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Metals and Alloys

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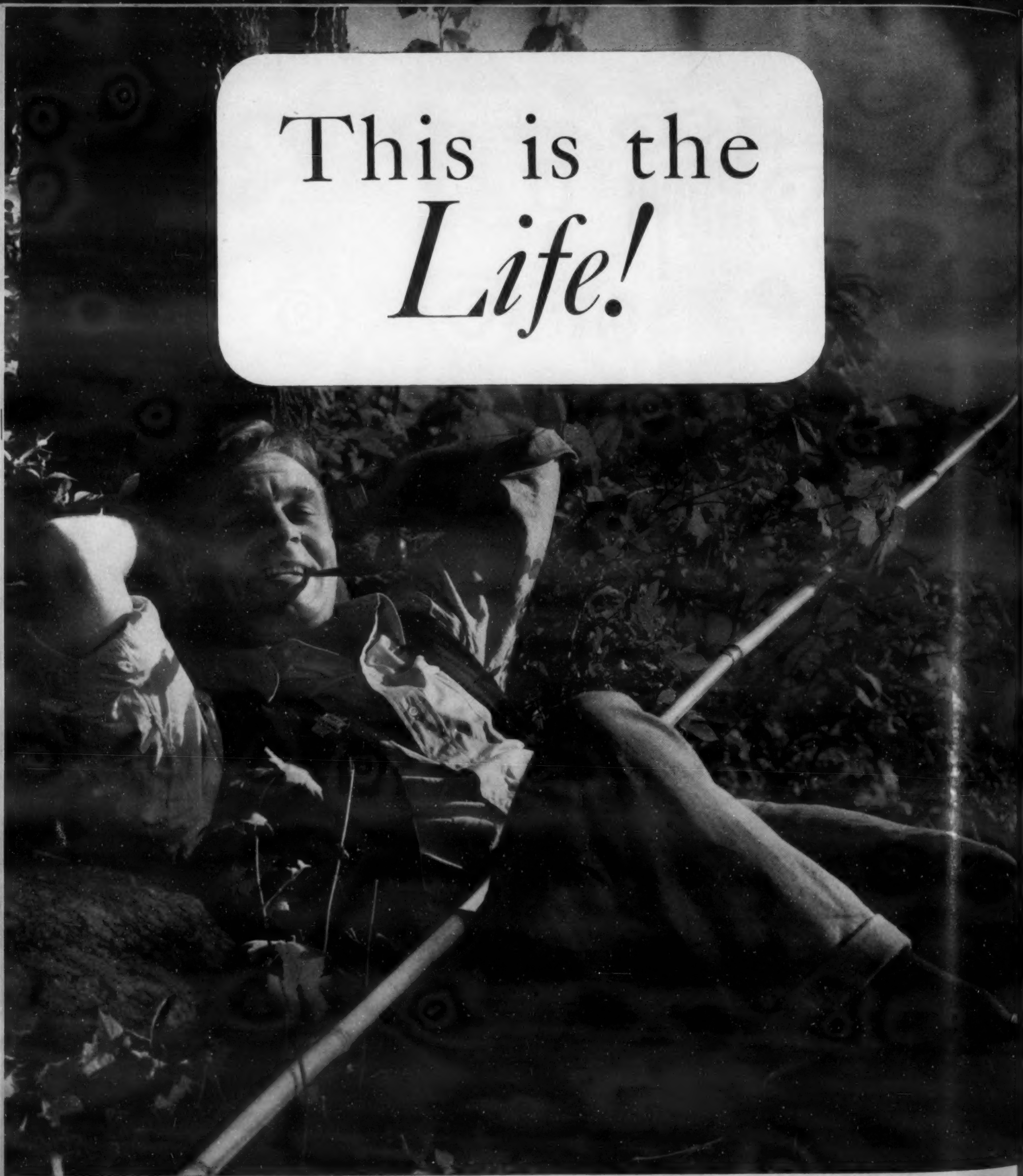
This is the
Life!

J. A. Clauss, President
Chief Engineer, Great Lakes Steel Corp.

Introduction

The 36th annual convention and iron and steel exposition of the Association of Iron and Steel Engineers will be held in the Stevens Hotel, Chicago, Sept. 24 to 27. It is pointed out that, owing to the tremendous demands heavy operations are placing on it, the American steel industry is faced with an immense rehabilitation program. Also that owing to the fact that in the last 10 yrs. less than half the annual capacity of the industry has been in operation, much of the installed equipment has lain idle and suffered marked deterioration and obsolescence.

These conditions are said to explain in part the fact that over 100 manufacturers of steel mill equipment have reserved 85 per cent of the available space in the Stevens Hotel. It is assured that thousands of the engineering and operating personnel of the steel industry will participate in the showing of the latest designs and developments in steel mill equipment and services.

A thoroughly supervised technical program has been prepared and future and present-day demands will be discussed by leading authorities. The tentative technical program and a partial list of the exhibitors follow:

Tentative Technical Program

The technical program, a tentative schedule of which follows, has been scrutinized by officials of the steel industry. Among some of the subjects to be discussed are: "Modern Electric Furnace Design and Practice," "Welded Construction of Blast Furnace Stoves," "Welded Open-Hearth Design," "Open-Hearth Furnace Control," papers on soaking pits and pit practice, and discussions on lubrication.

Attention is called to two inspection trips: One to the new hot and cold continuous strip mill at the Indiana Harbor Works of the Youngstown Sheet & Tube Co., and the second to the Wisconsin Steel Works of the International Harvester Co.

Tuesday, Sept. 24

Iron and Steel Exposition—
9:00 A.M.-10:00 P.M.

9:00 A.M.—REGISTRATION

9:15 A.M.—BUSINESS SESSION

Chairman: J. A. Clauss, Chief Engineer, Great Lakes Steel Corp., Ecorse, Mich.

Vice-Chairman: J. L. Miller, Asst. Chief Combustion Engineer, Republic Steel Corp., Cleveland, O.

9:30 A.M.—MECHANICAL ENGINEERING DIVISION

Chairman: George H. Rose, Chief Engineer, American Steel & Wire Co. Cleveland, O.

Vice-Chairman: T. E. Hughes, Maintenance Superintendent Carnegie-Illinois Steel Corp., Duquesne, Pa.

"Design and Operation of Gear Drives" by F. P. Dahlstrom, Mechanical Engineer, Farrell-Birmingham Co., Ansonia, Conn.

"Maintenance Shops in the Steel Plant" by T. R. Moxley, General Master Mechanic, Wheeling Steel Corp., Steubenville, O.

"Diesel Shifting Equipment in the Steel Plant" by E. M. Smith, Assistant Sales Manager, Electromotive Corp., LaGrange, Ill.

1:30 P.M.—ELECTRICAL ENGINEERING DIVISION

Chairman: I. N. Tull, Electrical Superintendent, Republic Steel Corp., Cleveland, O.

Vice-Chairman: H. W. Neblett, Development and New Design Engineer, Inland Steel Co., East Chicago, Ind.

"The Application of Demagnetizing and IR Drop Compensation to Cold Strip Mills" by G. E. Stoltz, Manager, Metal Working Engineer-

ing, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

"Modern Electric Furnace Design and Practice" by H. F. Walther, Assistant Melting Superintendent, Steel and Tube Division, Timken Roller Bearing Co., Canton, O.

"Mercury Arc Rectifiers for Main Roll Drives" by L. A. Umansky, Mining and Steel Mill Section, Industrial Department, General Electric Co., Schenectady, N. Y.

1:30 P.M.—WELDING ENGINEERING DIVISION

Chairman: L. J. Gould, Asst. Chief Engineer of Construction, Bethlehem Steel Co., Bethlehem, Pa.

Vice-Chairman: A. W. Steed, Maintenance Superintendent, American Rolling Mill Co., Middletown, O.

"Welded Construction of Blast Furnace Stoves" by H. C. Boardman, Chicago Bridge and Iron Co., Chicago, Ill.

"Welded Open-Hearth Auxiliaries" by C. C. Keyser, Welding Supervisor, Bethlehem Steel Co., Steelton, Pa.

"Building Up and Hard Surfacing" by L. Ames, Air Reduction Sales Co., New York.

2:00 P.M.—LADIES SIGHT SEEING TRIP AND TEA

10:00 P.M.—EXHIBITOR'S DANCE

Wednesday, Sept. 25

Iron and Steel Exposition—

9:00 A.M.-10:00 P.M.

9:00 A.M.—COMBUSTION ENGINEERING DIVISION

Chairman: H. T. Watts, Combustion Engineer, Republic Steel Corp., Gadsden, Ala.

Vice-Chairman: E. J. Wagar, Assistant Chief Engineer, Otis Steel Co., Cleveland, O.

"Effect of Pit Operation on Steel Conditioning" by Charles Labeka, Metallurgical Department, Pittsburgh Steel Co., Monessen, Pa.

"The Comparison of Soaking Pit Designs" by F. E. Leahy, Superintendent of Fuel Department, Youngstown Sheet & Tube Co., Youngstown, O.

"Soaking Pit Control" by M. J. Boho, Sales Engineer, Hagan Corp., Pittsburgh, Pa.

9:00 A.M.—OPERATING PRACTICE DIVISION

Chairman: H. G. R. Bennett, Engineer, Hot Rolling Mill, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

Vice-Chairman: J. D. Jones, Chief Engineer, Youngstown Sheet & Tube Co., Youngstown, O.

"Composition Bearings for Roll Necks" by H. R. Gilchrist, Lubrication Engineer, Carnegie-Illinois Steel Corp., Youngstown, O.

"Hot Scarfing of Billets, Blooms and Slabs" by E. A. Doyle, Consulting Engineer, Linde Air Products Co., New York, N. Y.

"Design and Operation of Continuous Butt Weld Pipe Mills" by J. H. Loux, Electrical Engineer, and E. T. Trebilcock, Assistant Electrical Engineer, Salem Engineering Co., Salem, Ohio.

(Continued on page 242)

11:00 A.M.—LADIES' LUNCHEON, CARD PARTY

12:45 P.M.—INSPECTION TRIP: Youngstown Sheet and Tube Co., Indiana Harbor, Indiana.

Thursday, Sept. 26

Iron and Steel Exposition—

9:00 A.M.-5:30 P.M.

9:00 A.M.—ELECTRICAL ENGINEERING DIVISION

Chairman: F. O. Schnure, Electrical Superintendent, Bethlehem Steel Co., Sparrows Point, Md.

Vice-Chairman: G. R. Carroll, Assistant Superintendent of Maintenance, Jones & Laughlin Steel Corp., Aliquippa, Pa.

"Reversing Drives for Slabbing Mills" by F. R. Burt, Engineering Department, Metal Working Section, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

"Power Requirements for Hot Strip Mills" by W. M. Ballenger, Steel Mill Engineer, General Electric Co., Chicago District, and T. R. Rhea, Steel Mill Engineer, General Electric Co., Schenectady, N. Y.

"Hot Strip Coilers and Their Drives" by R. A. Geuder, Application Engineer, Reliance Electric & Engineering Co., Cleveland, O.

9:00 A.M.—COMBUSTION ENGINEERING DIVISION

Chairman: M. J. Conway, Special Engineer, Lukens Steel Co., Coatesville, Pa.

Vice-Chairman: G. M. Coughlin, Combustion Engineer, American Rolling Mill Co., Ashland, Ky.

"A Survey of Open-Hearth Furnace Design" by W. C. Buell, Jr., Consulting Engineer, Cleveland, O.

"Relation of Flame Characteristics to Open-Hearth Operation" by A. J. Fisher, Fuel Engineer, Bethlehem Steel Co., Sparrows Point, Md.

"Open-Hearth Furnace Control" by M. J. Bradley, Engineer, Leeds & Northrup Co., Philadelphia, Pa.

1:30 P.M.—OPERATING PRACTICE DIVISION

Chairman: Albert W. Vincent, Asst. Superintendent of Blast Furnaces, Carnegie-Illinois Steel Corp., Gary, Ind.

Vice-Chairman: C. P. Betz, Asst. Manager, Hanna Furnace Division, Great Lakes Steel Corp., Ecorse, Mich.

"Developments in Blast Furnace Gas Cleaning" by C. H. Glaser, Superintendent of Blast Furnaces, Carnegie-Illinois Steel Corp., Youngstown, O.

"Rehabilitation of Blast Furnaces" by J. H. Slater, Assistant District Manager, Republic Steel Corp., Cleveland, O.

"Factors Affecting Production of Blast Furnace Gas" by J. S. Fulton, Special Representative, Ingersoll-Rand Co., Pittsburgh, Pa.

1:30 P.M.—LUBRICATION ENGINEERING DIVISION

Chairman: F. J. Thomas, Lubrication Engineer, Republic Steel Corp., Cleveland, O.

Vice-Chairman: H. H. Shakely, General Master Mechanic, Jones & Laughlin Steel Corp., Hot and Cold Strip Mills, Pittsburgh, Pa.

"Manufacture and Composition of Grease Lubricants" by Thomas Lennox, Socony-Vacuum Oil Corp., Trenton, Mich.

"Lubrication and Its Relation to Maintenance" by C. W. Phillips, General Master Mechanic, and R. A. Barta, Lubrication Engineer, Republic Steel Corp., Cleveland, O.

"Application and Care of Bearings in Steel Plant Auxiliaries" by F. L. Gray, Lubrication Engineer, Carnegie-Illinois Steel Corp., Gary Works, Gary, Ind.

7:30 P.M.—FORMAL BANQUET AND DANCE

Friday, Sept. 27

Iron and Steel Exposition—

9:00 A.M.-12:00 Noon

9:00 A.M.—INSPECTION TRIP: Wisconsin Steel Works, International Harvester Co., Chicago, Ill.

Feature Section

Pouring Crankshafts Continuously

The Ford Motor Co. is now pouring the celebrated cast steel crankshafts by a continuous melting process. The method is unique, striking and unusual. It is described for the first time.

Surface-Hardened Stainless Steel

A definitely new process for nitriding or surface-hardening stainless steel, especially for parts subject to wear, is described by Mr. Drever. This is also the first publication of this process.

Bearings and Strategic Tin

Tin is a strategic metal and it is used in many bearing alloys. We publish the first installment of a 4-part review of this broad and important subject by three metallurgical engineers of Battelle.

Decorations in Metals

Some strikingly beautiful decorations are now being fashioned from metals and their alloys. Reproductions of a few of those in the "S. S. America" are published.

Powdered Iron

The war has interfered with the usual supplies of much of the powdered iron which is used quite extensively in this country. The situation as to future supplies is ably discussed by Mr. Fellows.

Thin Layers of Metal

A new instrument for determining the microhardness or thin layers of metal is described—of wide interest to metallurgical engineers.

Letters to the Editor

An unusually large number of important discussions are presented this month.

Engineering Digests

Gray Iron

"Ever better" seem to be the watchwords of metallurgical engineers responsible for the quality of gray cast iron, judging from information on gray iron foundry progress given in a composite on page 316. Advances in cupola design, combustion control, sand practice, strength of iron and wear resistance are all reported.

Refining Non-Ferrous Metals

An up-to-date review of electrolytic refining progress by Heberlein (page 320) cites several interesting trends—the substitution of concrete for wood in refining tanks, the recovery of selenium and tellurium from copper anode slimes, and the electrolytic recovery of silver and gold from precious metal scrap.

What's Weldability?

An assortment of experts examine the term "weldability" and seek an accurate definition on the basis of steel behavior, in an article in *Welding Journal* (page 326). For evaluating weldability, some advocate compilation of S-curve data, and others recommend simply making a joint and comparing its properties with the original metal.

Bright Zinc Plating

Bright zinc coatings can be produced directly (without prior removal of bath-contaminating metals) in cyanide baths containing certain additions, reports Smith in a composite on page 339, and Hull describes magnesium- or calcium-containing zinc anodes that prevent zinc build-up in the bath.

Metal-Sprayed Bearings

Shaw (page 346) finds metal-sprayed bearings to have lower friction and higher seizure loads than bearings cast from the same materials.

High-Temperature Alloys

A useful review of materials for service at elevated temperatures is offered by a composite on page 344, which covers cast irons, low-alloy irons, high-chromium alloys, and alloy steels.

REVERE INDUSTRIAL EXTRUDED SHAPES OFFER THESE TIME-SAVING ADVANTAGES:

WIDE VARIETY—the extrusion process produces cross-sections of unusual forms with wide variety of slots, grooves, contours and angles. These forms, when cut in suitable lengths, can in many cases take the place of simple forgings, sand or die castings, at a considerable saving in time, tool cost, metal cost and finishing cost.

FEWER OPERATIONS—and a shorter time per operation are required with Revere Industrial Extruded Shapes. In fact, milling or machining operations needed with stock rods are reduced because Revere Extruded Shapes are made in the desired profile.

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Trends

If Cone will give us the temporary loan of the title of one of his departments, we might comment on a trend that has long been in evidence, but never so clearly as in recent years. This is the tendency toward special meetings of metallurgical groups.

We can recall when the only meetings were the annual ones of the regular societies. Then came the chapters, with their monthly meetings, and the annual meetings of local sections or groups of chapters. Then arose the Bureau of Mines-Carnegie Tech. meetings on physical chemistry of steel making, those of the Metallurgical Advisory Committee to the Bureau of Standards, of the Open Hearth Committee, etc., and, in more recent years, the numerous special conferences held at universities, with or without the cooperation of a national technical society or some subdivision thereof.

Some of these conferences arose from a real desire of the metallurgists of a given region for a type of adult education fitted to their particular local needs. Others, of course, were primarily motivated by the desire of a professor to impress the dean or the president that the professor is a live wire, able to command the cooperation of experts of high standing whose presence on the program will insure a large attendance. Whenever one of these conferences went off well, and they often did while they were a novelty, the urge to make it an annual affair was overpowering.

On the whole, the conferences are a good thing, and, within limits, are worth continuing. The youngster, who thus secures contacts he could not otherwise get, with leaders in his field, appreciates them, and those leaders have a responsibility to the youngsters, which, so far, they have discharged nobly.

Some of the "summer schools" that last several weeks and go into one subject deeply, really accomplish something. These drink deeply and are in a different category from the conferences that merely taste from a varied list of topics. The latter far outnumber the former.

The trend shows signs of rising to a point where, we suspect, the law of diminishing returns is about to apply. With so many meetings that one is expected to attend, the urge to attend any particular one decreases. We belong to half a dozen technical societies with more or less regular local or group meetings near by. If we were sufficiently conscientious, we could spend lots of evenings in that way, few of which would be productive of information not otherwise obtainable.

Then, at least once or twice a month there is some special meeting or conference, at a distance, taking from a day and evening to three full days, the topics of which are admittedly of interest. The time required in attending these would take a big slice out of what time there is. Sooner or later, the worthwhile information brought out at these conferences will get published, and we can read and study it at such times as best fit our own convenience.

When these events were scarcer, they were really events. There's no novelty in them now. So much for the listeners.

The speakers, too, get sort of moth-eaten. One with a reputation is asked to appear all over, too often to do a good job on preparation for each particular audience, so that actually a talk by local talent clicks better than most of those by the "big names."

If an inordinate amount of time and travel expense of speakers is called for, which expense falls on the employers of the speakers, as it almost invariably does, it is little wonder that, in subconscious justification for that time and expense, some speakers tend to let their messages degenerate into thinly disguised sales talks. At any rate, far too many of the talks to local chapters by out-of-town dignitaries are a pain in the neck, courteously endured by the audience and written up by the local reporter as just the opposite of the flop it really was.

We've been on both the receiving and the transmitting end. We remember one talk we made before a section of the American Chemical Society that was a terrible flop, the topic wasn't of any real interest to that audience, though it had gotten by with a metallurgical audience. The program committee should have known better than to ask us to repeat that talk to that audience, and we should have known better than to give it.

The program committees for these meetings and conferences have a real task. They might try the experiment of scheduling fewer meetings. The chances are that a few good ones would benefit metallurgy more than the present plethora of mediocre ones. It's possible to work a good idea to death.—H. W. G.

Ford Cast Steel Crankshafts Now Poured Continuously

BY EDWIN F. CONE

THE SUBSTITUTION BY THE FORD MOTOR CO. of a cast for a forged steel crankshaft for its passenger cars several years ago was an event of broad metallurgical interest. Such a step, however, was not taken without mature consideration accompanied by extensive experimentation and research. Ever since the Ford company initiated the production of a crankshaft of cast steel, one of the aims of that progressive organization has been to develop the process from an intermittent to a continuous melting and pouring operation.

The metallurgical story of the development of this new type of crankshaft was told by METALS AND ALLOYS late in 1935.[1] Until quite recently or early in 1940, the several million crankshaft castings, which have been made and put in service, have been cast from a cold charge, melted in an electric arc furnace. In developing a continuous melting and pouring process to replace the cold-charge-electric furnace method, Ford metallurgical engineers have used as a working model the present continuous melting and pouring process for cylinder blocks of cast iron. This highly interesting process was described[2] in METALS AND ALLOYS in November, 1935.

The continuous melting and pouring of cast iron is a different problem from that of handling the copper-silicon high carbon steel for crankshafts. It will be recalled that, for the cylinder blocks, metal from the blast furnaces and cupolas is transferred to a mixer and from this to an electric arc furnace for superheating. Composition is easily regulated at this stage. From the arc furnace the metal flows into a forehearth, heated with powdered coal, from which it flows from each end to the continuous pouring equipment.

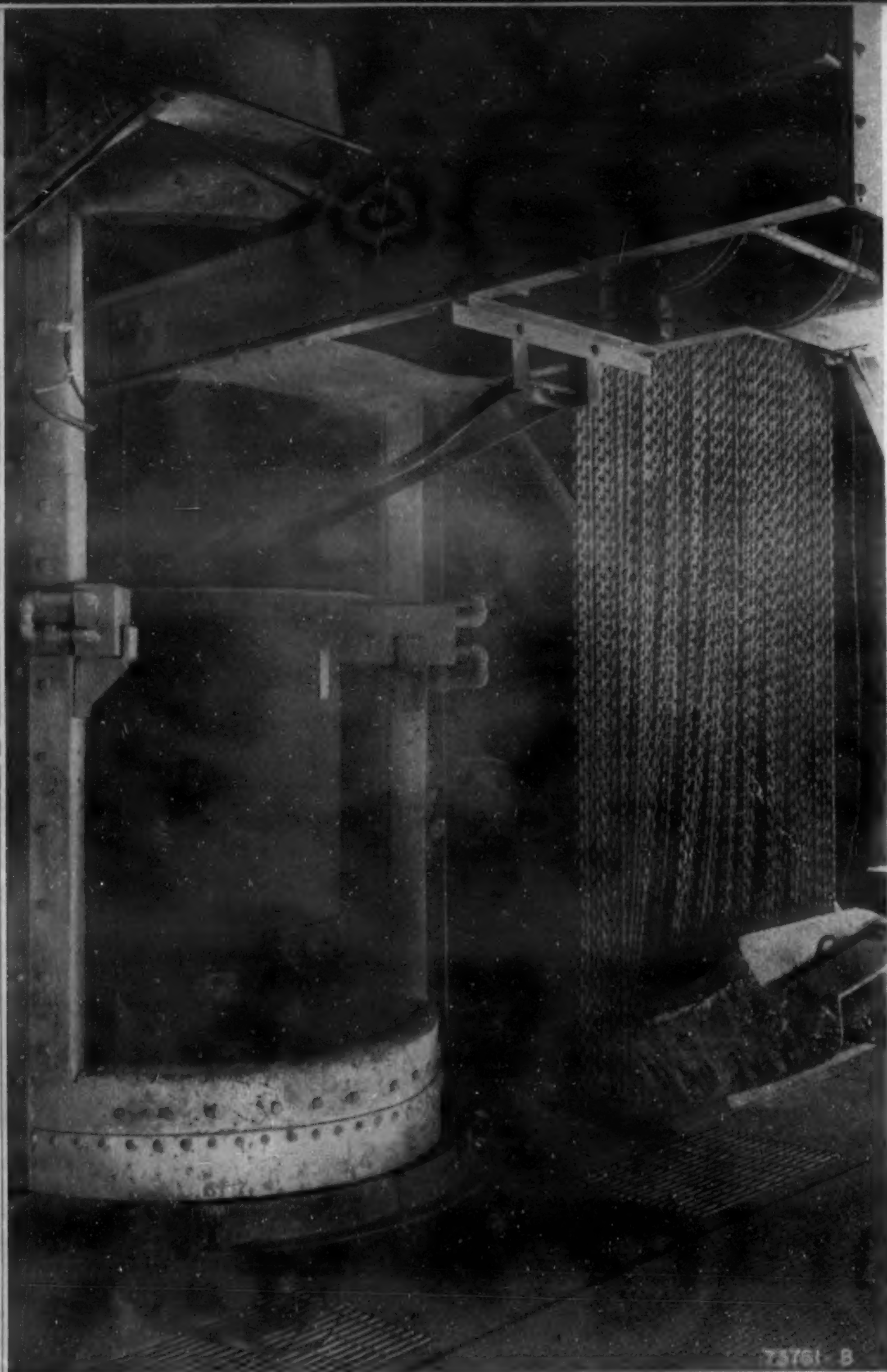
To develop a similar or better method for the crankshafts, the problem was one of economy as well as of metallurgical control. Since the advent of the steel crankshaft in 1933, the Ford metallurgical engineers have had it in mind to melt and pour the steel continuously.

Steps in Developing the Process

The first attempt was to use an air furnace, fired with pulverized coal, supplemented by a conventional cupola—cupola-air furnace manipulated metal. This did not prove entirely satisfactory, due to the fact that an oxidizing flame had to be used in the air furnace in order to reduce the high carbon in the metal from the cupola. This oxidized metal was not of the best quality and the analysis was very difficult to control, especially when it is necessary to obtain a metal averaging 1.35 to 1.60 per cent C.

The next attempt was made with an oil and steam-fired cupola which was provided with a small receptacle for holding a small bath of molten metal at the base. Due to the drastic impinging action of the flame on the refractories, this arrangement did not prove satisfactory. Metal made by this process, however, was better than in the first trial method.

From the experience thus obtained, the third and present method was developed. It was decided to build a furnace that would combine the stack charging and continuity of a regular cupola with the



Each cupola, or stack, has an opening through which the bucket, filled with a charge, is inserted at the charging floor level by means of a crane. A protection curtain of chains can be swung in front of the opening when the charges are not being dumped.

hearth and chamber similar to a pulverized coal-fired air furnace. The flame from the combustion of the pulverized coal would sweep across the long bath in the hearth and on up the stack, thus preheating and partially melting the incoming charge.

The New Process

This theory has been carried out and put into commercial operation—the charge is put into the side near the top of a long cupola at the bottom of which is a long air furnace hearth. The products of combustion from the powdered coal, which enters the air furnace at the end farthest from the stack, sweep through the hearth and up the cupola stack—this equipment may be regarded as an air furnace with a long high stack which is used for supplying the furnace with partially melted metal.

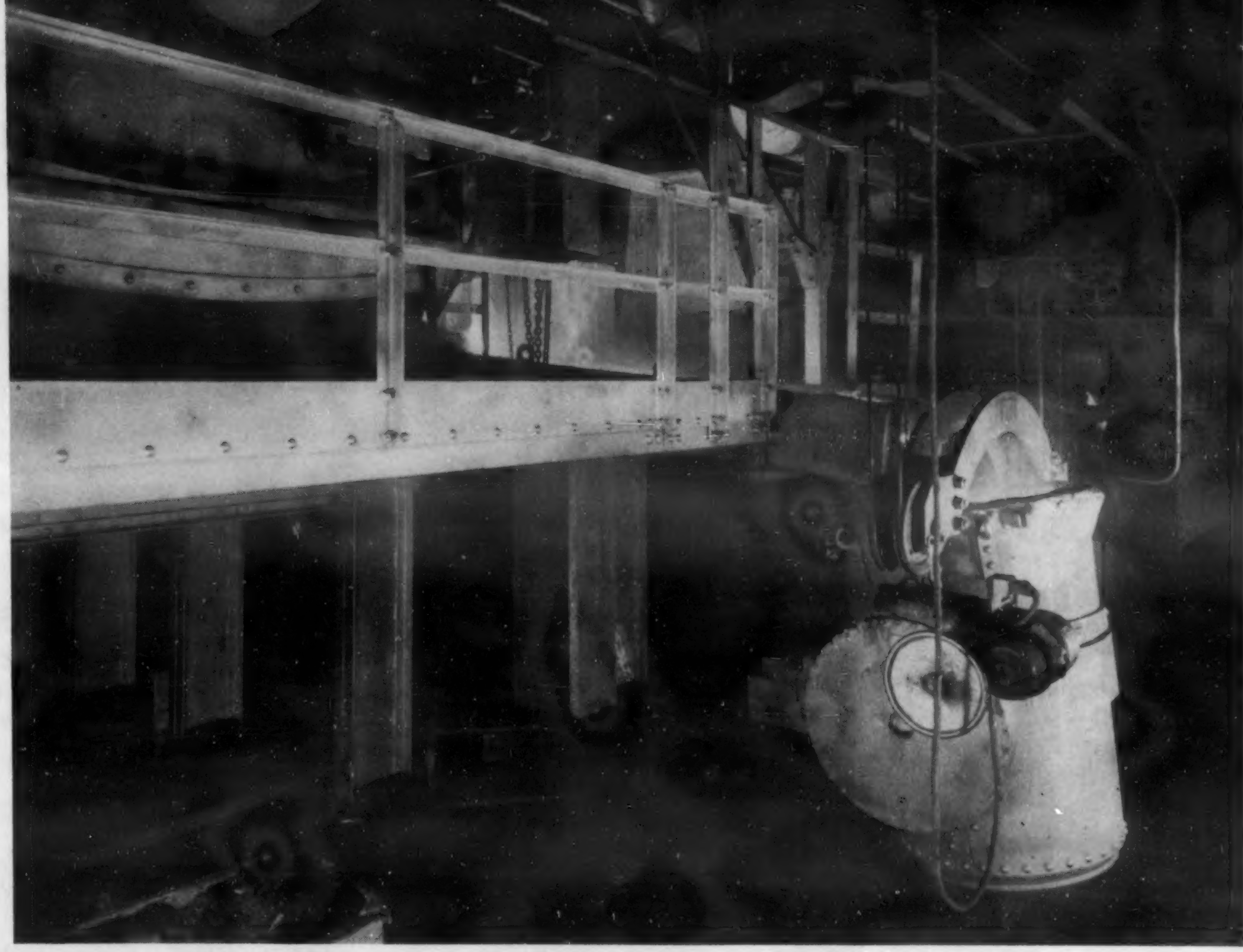
The charge placed in the cupola stack can be depended upon to be the same as to composition as when charged—there are virtually no chemical reactions in the stack or furnace. The flame, sweeping across the hearth of the air furnace bath, melts the charge at the base of the cupola or stack, from whence it pours continuously into the hearth. A suitable stock yard is supplied with the raw materials from which the proportions of each material are selected, weighed and charged into the side of the cupola by a 1-ton bucket every 4 min. By means of a crane the 1-ton bucket is swung into the open door in the side of the cupola and dumped by opening a false bottom.

The Charge Used

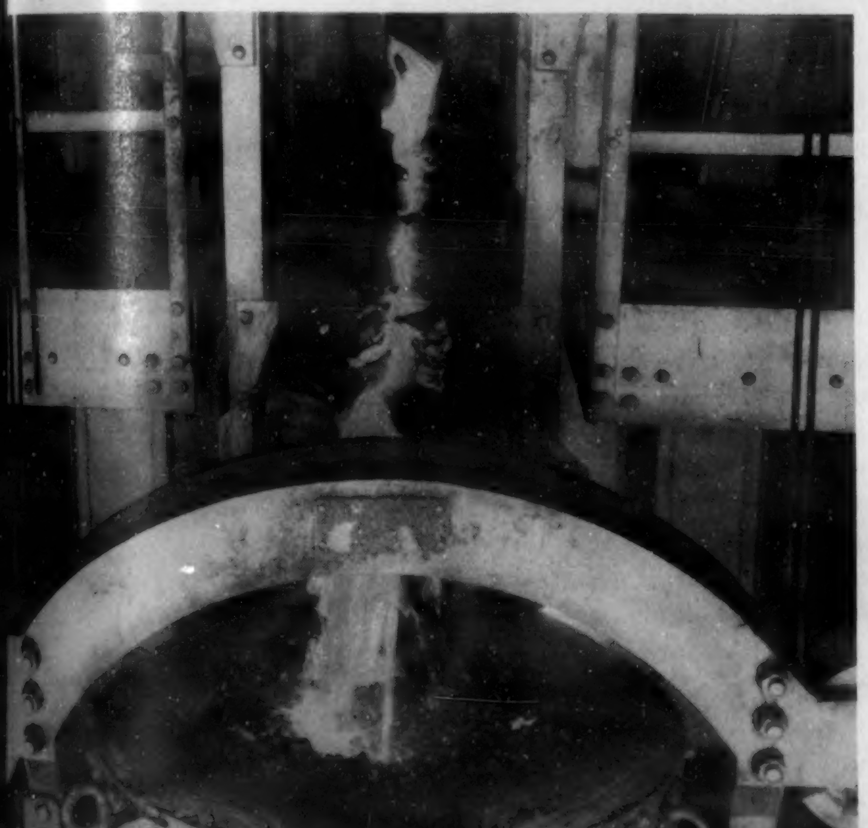
Each charge consists generally of the following materials:

A charge had just been released, as this photograph was taken. Some pyrotechnics are always in evidence at this time.

Another view of the metal flowing from one of the fore-hearths into the transfer ladle.



Below: The metal flowing from the end of one of the fore-hearths into the transfer ladle.



	Per Cent
Return scrap (crankshaft)	40.0
Basic pig (2% Si)	20.0
Briquetted borings	40.0

This charge, as it melts at the base of the cupola and is further melted and brought up to suitable temperature in the air furnace or forehearth, has approximately the following composition:

	Per Cent
Carbon	1.50
Silicon	1.00
Manganese	0.80
Copper	1.50
Chromium	0.15 to 0.18

Detailed data are not available as to the dimensions of this equipment but the construction and dimensions are essential factors in the success of its operation. In general the forehearth slopes down toward the tapping spout but enough molten metal is continually in the hearth under the stack or cupola so that the incoming charges rest in molten metal.

The throat or base of the cupola or stack is so contracted or pinched in that the charges do not come down too rapidly. The size of the opening in this throat is of particular importance—too small a throat would cause the charge to pack up, thus decreasing the passage through which the products of combustion could escape. On the other hand, if it were too open, the flame could escape too easily, resulting in less efficient heating.

Metal from the forehearths being poured into one of the electric furnaces for preheating.

Specially Built Cupolas

The diameter of each of the two cupolas or stacks is 36 in. Their total height is approximately 25 ft. with the opening or door for charging 15 ft. from the foundry floor level. The height of the forehearth above the foundry floor is about 10 ft. The roofs of the forehearths are arched and the lining of the arch and side walls is a mullite base brick. A high density, high fusion neutral clay brick is used to line the bottom. For lining the cupola or stack, fire brick are used with the throat lined with mullite brick. The amount of powdered coal consumed per ton of steel tapped from each hearth averages about 300 lbs. The capacity of each forehearth-cupola set-up is about 15 tons per hr.

At the present time no attempt is being made to pour the crankshaft castings directly by means of a pouring car from this forehearth. This may be a possibility for the future. Instead the metal is tapped from the forehearths into 8-ton transfer ladles, its temperature being about 2700 deg. F. The metal is then transferred to 15-ton electric arc furnaces where it is super-heated to about 2900 deg. F. During this brief period, analyses are made in the spectrographic laboratory, and alloy and other additions are made if any are necessary to bring the metal to the desired composition.

From the electric furnaces the metal is conveyed in transfer ladles to a rocking type of holding furnace, fired with powdered coal. From this the metal flows continuously at about 2800 deg. F. into a pouring car similar to that used in the continuous pouring of cylinder blocks.[2] This pouring car, taking metal continuously from the holding furnace, pours simultaneously two molds of 4 crankshafts each, the pouring temperature of the molds being 2700 to 2750 deg. F. This is pointed to as eliminating all ladle men pouring on the line as was the case when pouring metal direct from a cold charge in electric arc furnaces.

The continuous supply of steel from the cupola-forehearth equipment, together with the holding furnace and the continuous pouring equipment, makes it possible to pour many more crankshafts per day as against the output by the older process which this displaces.

Present Composition of the Metal

There has been very little change in the composition of the crankshaft metal since that made public in our first article.[1] The composition as announced in 1935 and that used at present as made public last January in a paper[3] by McCarroll and Jeter before the local Detroit chapters of the A. F. A. and the A. S. M. is as follows:

	1935	1940
Carbon	1.35 to 1.60	1.35 to 1.60
Manganese ...	0.60 to 0.80	0.70 to 0.90
Silicon	0.85 to 1.10	0.85 to 1.10
Copper	1.50 to 2.00	1.50 to 2.00
Chromium	0.40 to 0.50	0.40 to 0.50
Phosphorus ...	0.10 max.	0.10 max.
Sulphur	0.06 max.	0.08 max.

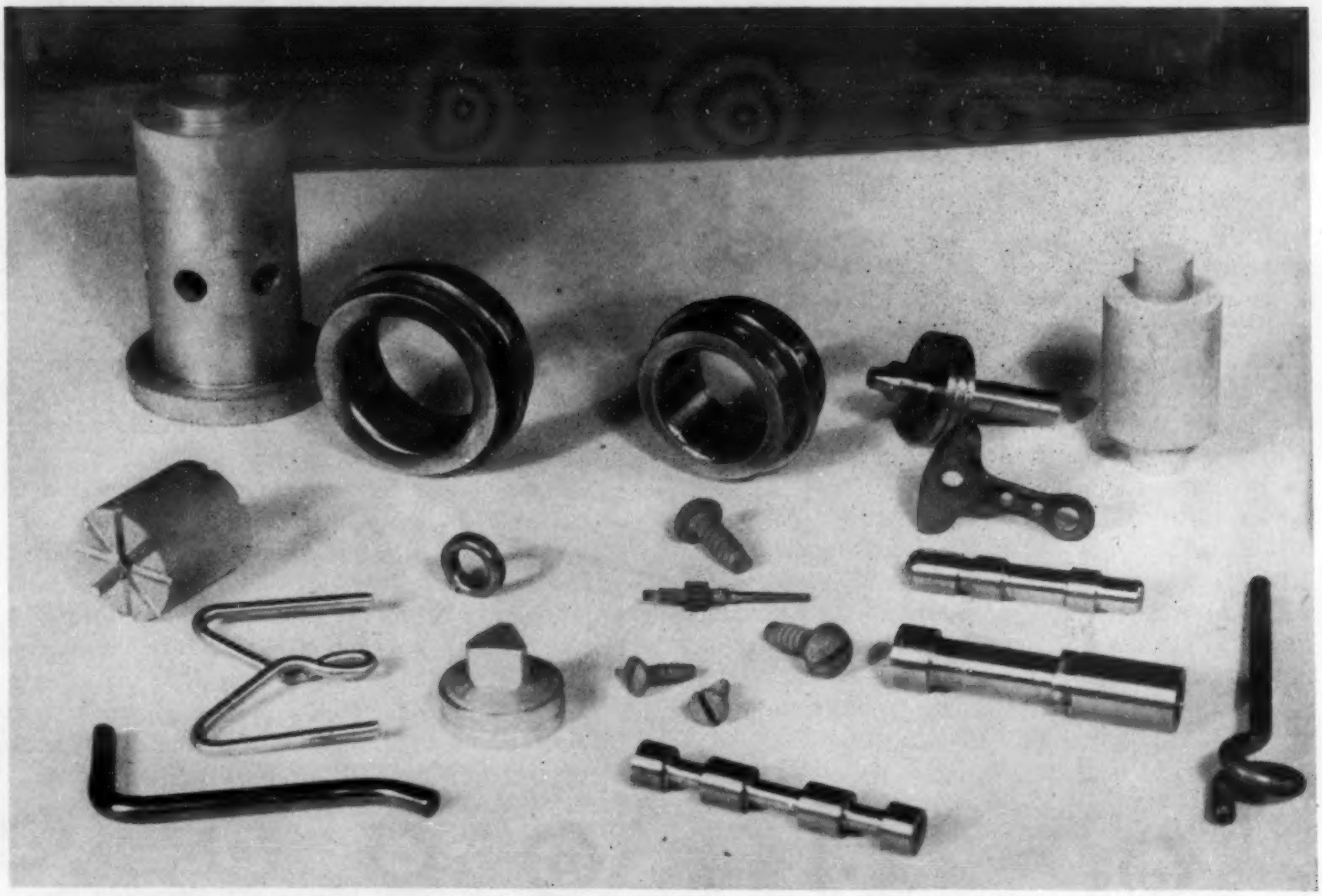
The only changes at present in effect as contrasted with the inception of the crankshaft are a slightly higher manganese range and a higher permissible sulphur content.

This unique and highly interesting cupola-forehearth equipment is not only a metallurgical achievement of decided merit but is also another step in the general policy of Ford metallurgical engineers of melting and pouring castings continuously wherever possible. Continuous operations of this nature not only save time but also, it is claimed, produce more uniform castings because the metal for each casting is delivered at uniform temperature. Besides the cylinder blocks and the crankshafts, continuous pouring is also used in producing the centrifugally cast gear blanks,[4] passenger car transmission housings, and flywheels. In fact the entire Ford foundry is being revised and enlarged in order to go into volume production of cast steel tractor parts and other products.

References

1 "The Story of the Ford Cast Crankshaft," *Metals and Alloys*, Vol. 6, Oct. 1935, pp. 259-263.
2 "Continuous Pouring of Ford Cylinder Blocks," *Metals and Alloys*, Vol. 6, Nov. 1935, pp. 299-302.
3 "Cast Steel Tractor Parts," *The Foundry*, February, 1940, Vol. 68, pp. 30-33, 86.
4 "The Metallurgical Story of the Ford Centrifugally Cast Steel Gears," *Metals and Alloys*, Vol. 9, Oct. 1938, pp. 276-279.

Nitrided Stainless Steels



A few nitrided stainless steel machinery parts and other nitrided stainless steel products.

The product and process described for the first time in this article offer the designer and engineer, in effect, a new material—a metal with the strength, toughness and general corrosion resistance of stainless steel plus surface hardness and wear resistance of the highest order. New fields of application for stainless steel—already serving innumerable engineering purposes—are obviously opened up, and several are cited by the author. The article will also interest everyone concerned with case hardening, since it describes such a novel application of this type of treatment.—The Editors.

by HORACE DREVER
President, The Drever Co., Philadelphia

IT HAS LONG BEEN RECOGNIZED that if the unique corrosion resisting properties of the stainless steels could be combined with a hard, abrasion resistant surface, the field of usefulness of these alloys would be greatly extended, and this combination of properties would materially improve stainless machinery parts and other stainless articles where resistance to wear is required.

The ordinary alloys of iron have since time immemorial been processed to obtain a hard surface with a tough, ductile, shock-resistant core, usually by case hardening in a carbonaceous atmosphere or material; a high carbon surface is produced, which can be heat treated by ordinary well-known methods to harden the surface. Also, modern industry extensively uses special alloy steels of the so-called "Nitralloy" type after subjecting them in each case to a process that produces a nitrided, exceedingly hard surface. In addition to these methods of surface hardening the production of a shallow, hard case by cyaniding is universal practice.

Inasmuch as these very useful materials have found widespread application, and have made available to the designer the exact material he requires for many purposes, it is only logical to assume that iron alloys of the stainless class would be benefited in many cases by a process for producing characteristics similar to those outlined above, i.e., a hard surface and a tough core.

It is the purpose of this brief article to announce that a practicable process for surface hardening these steels has been developed and is now available.

Stainless steels can be briefly described as alloys of iron containing more than 11 per cent Cr with or without the addition of other elements such as nickel, manganese, molybdenum, sulphur and columbium, and are characterized by a relatively high resistance to corrosion when compared to other ferrous and non-ferrous alloys. Their field of usefulness is tremendous, but in the past this field was ofttimes limited by the engineer's inability to get desired physical properties combined with corrosion resistance. This new process goes far toward expanding the field of usefulness and reducing the limitations. By this process it is possible to secure the corrosion resistance properties offered by one or all of the many stainless alloys and at the same time obtain a finished part with an extremely hard wear and abrasion-resistant surface. No new trick alloys are needed. Any of the standard stainless alloys, including those especially designed for free machining qualities, respond satisfactorily to this process.

The Nitriding Process

In the new process of nitriding or surface hardening, these steels, the outer layer of the material is impregnated with nitrogen, presumably in the form of nitrides, to a depth that varies with the type of steel and the time under treatment. It is found that in general a depth of 0.008 to 0.030 in. will suffice for the great majority of purposes, the depth of case being determined individually for the type of service to which the article will be put. Some types of steels will nitride more readily than others and, in general, the steels that have no nickel present will be more readily nitrided than those with nickel, under the same conditions of time and temperature.

The new process is quite flexible and can be adapted to treat parts of special and intricate design. Since the surface hardening depends on gas penetration and absorption, it is possible to harden keyways, tube or bearing interiors and in fact any surface which can be exposed to the gas. However, if it is desirable to harden one section and retain a soft surface elsewhere, means are available for inhibiting or stopping-off these surfaces and preventing their hardening.

Because of the inherent corrosion resistance of stainless, it is possible to buff or polish the nitrided surface. This is highly important where an extremely smooth and hard surface is desirable, in connection with high corrosion resistance.

The question of distortion and dimensional changes caused by the new nitriding process will require further investigation, but preliminary test indicates that if fundamental rules are followed during the processing, the distortion is negligible and not measurable. There is slight dimensional change during nitriding, but this would not be sufficient, except in rare cases, to cause trouble. In these extremely close tolerance cases, a surface grinding or lapping operation would be sufficient to correct this dimensional change and would in no way affect the hardness of the case.

The actual process is carried out in furnaces of orthodox types at moderate temperatures, i.e., approximately 1000 to 1100 deg. F. A muffle that can be made entirely gas-tight is used and the processing gas let in and out in the usual manner of nitriding, with an effort made to keep approximately constant pressure throughout the process.

The gas used is derived from anhydrous ammonia and is used in two states. During the preliminary part of the cycle the ammonia vapor is dissociated and after purification and activation is admitted to the nitriding chamber to sweep out all traces of air that may be present. It is supposed that this preparatory treatment also eliminates much of the air that closely surrounds the stainless parts in what might be termed, for want of a better designation, molecular adhesion. After this preliminary purging, ammonia vapor, after being activated in a silent electrical discharge to ionize the gas, is admitted to the nitriding chamber. In the actual nitriding, ammonia gas is dissociated partly, the nascent nitrogen being absorbed by the material and the hydrogen that is released passing out of the muffle together with the undissociated gas. The essential of the process is the ionization of the gas before admittance to the nitriding chamber. This is fully covered by United States Patents.*

Properties of Nitrided Stainless

After the material is nitrided, its physical characteristics in respect to tensile strength, elongation, yield point, impact value, and reduction of area remain approximately the same as in the original material, but its surface hardness has increased to a vast extent. Hardnesses up to 1050 Vickers Brinell are secured.

It is also found that these hardnesses are maintained to a relatively high degree at elevated temperatures. For instance, a sample of "18 and 8" stainless steel, Type 302, was nitrided to a depth of 0.010 in. and tested on the Vickers machine with the following results:

Test Temperature Deg. F.	Vickers Brinell Hardness
70	1050
1000	710
1100	540

This is to be compared with the same steel before nitriding, when the hardness will be not greater than 145-160 Brinell at room temperature.

Since the principal object of surface hardening these steels is to produce wear-resistance, it is interesting to note the comparative tests on these materials in a standard type of reciprocating wear-testing machine. The Table indicates the relative amount of wear of two classes of stainless steels before and after nitriding, and of Stellite, which is frequently used where corrosion and wear-resistance are required.

Abrasion Loss of Nitrided Stainless Steel and of Stellite

	18 Cr, 8 Ni—Type 302		12-14 Cr—Type 410		Stellite
	Normal	Nitrided	Normal	Nitrided	Normal
Loss in weight, gms./100 gms..	0.85	0.002	3.35	0.018	0.0358
Number of strokes at 100 lbs. pressure	6,000	30,000	10,000	50,000	30,000

The principal reason for using stainless steel is, as the name indicates, to insure resistance to corrosion, and this phase of the subject is of paramount importance. It should be stated at this point that the corrosion resistance of all classes of stainless steel is somewhat impaired by the process of nitriding, but for a vast number of applications not sufficiently to be in any way detrimental. Nitrided stainless is not recommended for use in contact with the heavy acids, such as nitric acid. No apparent effect on the corrosion resistance is noted for these materials in contact with high-pressure high-temperature steam, gasoline, kerosene and fuel oil, ordinary city tap water, and many other corrosive agents. In alkaline boiler feed water at 380 deg. F. the material stains lightly but does not etch or pit, and would be given a Class B rating under the A. S. T. M. rating system.

In the salt spray test, independent laboratories have reported widely different results, which cannot be reconciled at this time, but it is sufficient to say that the resistance to salt spray is impaired to an extent undetermined at the present time. Data on this are now being accumulated and will be reported at a future date, together with results of long-time immersion in sea water and long-time tests under alternate immersion in sea water and exposure to air. Because of the great number of types of stainless steel that are now in common use it necessarily will take a considerable period of time to give a qualitative rating to cover the general class.

Some Uses

Considering the characteristics of stainless steel as nitrided by this process, the indicated uses are many and various. For instance, it is found to be an exceedingly valuable material for valve seats of high-pressure high-temperature steam valves where abrasion, "wire cutting" by the steam, and corrosion combined with high temperature are prevalent. There are a multitude of uses in textile machines for wire guides, eyelets, etc. In the oil industry it can be used for pump shafts, valve seats, high-pressure valves and parts of oil-well pumps and plungers. Under special conditions stainless steel roller chain for power transmission purposes are required. Nitriding of the bushings and pins for these chains is entirely practicable and will add extensively to the life of the parts making up the chain.

Other possible uses indicated from the physical character of the material are internal combustion engine liners and valves, pumps for organic chemicals, moving parts of instruments for use under marine conditions and many others too great to be mentioned here. Actual data from service tests are being accumulated and will serve as a guide to the engineer in correctly determining the applicability of this process or its products in specific instances.

* U. S. Patent No. 1,975,063—Sept. 25, 1934. U. S. Patent No. 1,975,064—Sept. 25, 1934. U. S. Patent No. 2,131,709—Sept. 27, 1938. U. S. Patent No. 2,131,710—Sept. 27, 1938. U. S. Patent No. 2,188,137—Jan. 23, 1940.

Bearing Metals from the

by H. W. Gillett, H. W. Russell and R. W. Dayton

Battelle Memorial Institute, Columbus, Ohio

TIN, and to a lesser degree antimony, are classed among "strategic" materials, i.e., those essential in the national defense, but which the United States does not produce in quantities sufficient to supply even normal industrial requirements. The possible disturbance of trade relations so as to hamper importation would create a situation of scarcity which can be guarded against in two ways, by suitable "stockpiles" and by the use of alternative materials of which there is ample domestic supply.

Bearings are one of the most vital uses of tin and antimony. Both metals are used in babbitt, and tin is used in bearing bronzes. Engineers are so accustomed to specifying babbitt bearings or bronze bushings that at first sight it would appear that a lack of the raw materials for them would create a very serious situation. The predicament seems even more desperate when it is realized that substitution has long been sought on a purely peacetime economic basis without such substitution having been widely accomplished.

Nevertheless, that search for equivalents of babbitt coupled with the search for bearing metals of properties superior to babbitt, has developed enough other classes of bearing metals adequate as engineering substitutes to make it clear that, even though the tin supply were cut to the merest dribble, good bearings could still be supplied in adequate quantities. Lack of tin would be an inconvenience in the bearing metal industry, but it would not stop our wheels from turning. The effects of a lack of tin would not be felt as much by the users of machinery, who would not experience troubles with bearings, as by the bearing manufacturers, who would find that bearings of substitute materials in general would be more difficult to produce, and, by the builder of the machinery, who would need to be certain that any necessary modifications in design were taken care of.

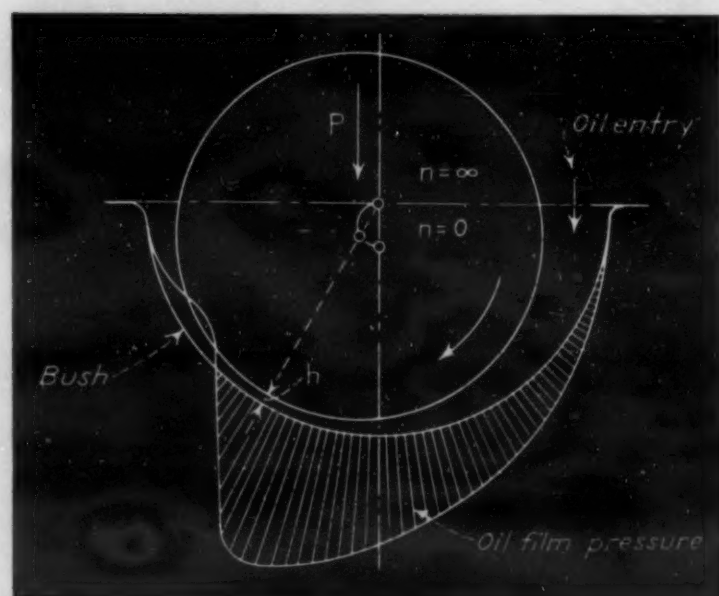
Sleeve Bearings of Babbitt or Bronze

A complete treatise on bearings and bearing metals would cover a large field. Here we shall concern ourselves only with those applications for which sleeve bearings of babbitt or bronze are now in general use. There are many bearings whose requirements are so far from severe that cast iron or oilless bearings made from powdered iron by powder metallurgy methods will serve, or where the shaft may safely run in brass or in a zinc-base die casting. There are severe duty bearings where steel ball, roller or needle bearings are required, and of course some machines, now using split sleeve bearings for ease in assembly, could be engineered to use ball or roller bearings, if the expense of such bearings could be borne.

The vital industrial uses for bearing metals containing tin are in the precision, heavy duty sleeve bearings of the automobile, truck, bus, tractor and like gasoline and Diesel engines, in pumps and general machinery and, though they do not class as precision bearings, in railroad rolling stock. We shall confine our attention to these general types, which operate at relatively high loads and high speeds.

From the extensive literature of bearing design, lubrication and the metallurgy of bearing metals we shall cull only such features as appear essential to our particular subject, the feasibility of the replacement of tin. No attempt will be made to discuss or even to assemble a bibliography upon the many

Fig. 1. Oil film pressure diagram of a journal bearing with a smooth brass. Falz[3].



Point of View of Strategic Materials—I

phases of the general topic that would be important in a general treatise.

Before one can appraise the other metals and alloys that might be substituted for tin base babbitt and for bronze, it is necessary first to consider those factors in a bearing assembly that have *no* direct relation to the materials, those features that depend upon the load to be carried, the speed and the dimensions of the bearing.

We shall not be successful in wholly eliminating the topic of materials from this section of the discussion, because the bearing temperature is a function of the pressure and speed, and of the amount and mode of lubrication. The properties of the bearing metals are so affected by temperature that the operating limits are set thereby. Nevertheless, if we first discuss bearing assemblies operating under such temperatures that *any* bearing metal might be used, the way will be paved for later consideration of operating conditions that do require a choice of materials.

The Fluid Film Theory

The generalized discussion of bearings without reference to materials comes primarily from the students of lubricants, who have set up the "fluid film" theory of lubrication. They calculate that, in a bearing assembly of given dimensions (and with adequate stiffness) the coefficient of friction is not affected by the materials of the shaft or bearing, nor by the composition or "oiliness" of the lubricant as long as there is an ample supply of lubricant. It is affected by the pressure on the bearing, the speed of the shaft and the viscosity of the lubricant at the operating temperature. It is immaterial whether the lubricant be oil or, say, sugar syrup, if the viscosity is the same. All three of the variables have to be taken into account, and it is found that the coefficient of friction increases with the viscosity (usually measured in centipoises) denoted by Z; increases with the speed (usually measured in r.p.m.) denoted by N; and decreases with pressure (usually measured in lbs. per sq. in.) denoted by P. It has been found that the coefficient of friction is a function of $\frac{ZN}{P}$,

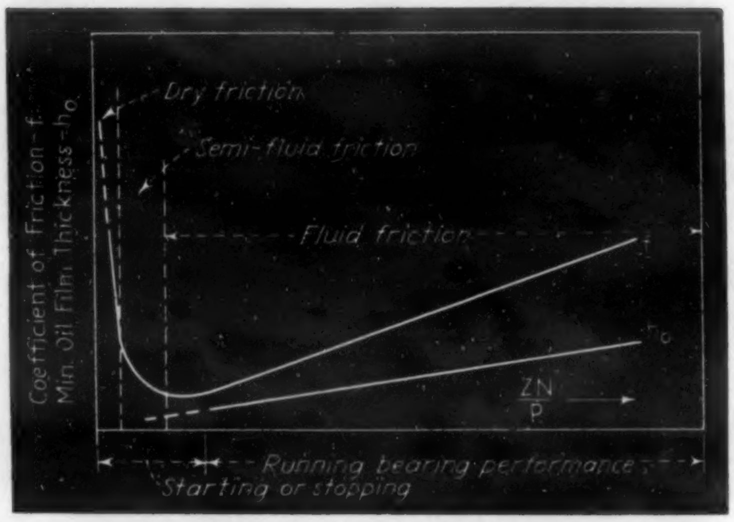


Fig. 2. Journal-bearing performance. (When starting or stopping, the bearing usually performs in the regions of dry and of semi-fluid friction). Tichvinsky & Fischer[6].

being low at low $\frac{ZN}{P}$ values. This expresses the fact that the fluid friction is within the oil layer and is due to the effort required to shear the layer and allow rotation. It is postulated that there is no relative motion between the shaft or bearing surface and the oil in immediate contact, that is, the oil is held upon the metal surface as if it were frozen in place. Then, in a bearing with the shaft rotating and with a *complete* film of oil separating shaft and bearing, the materials of the shaft and bearing are supposed to play no part; everything is occurring in the oil. Thus the $\frac{ZN}{P}$ relation tells us that the coefficient of friction

(1) decreases when a less viscous oil is used or a given oil becomes less viscous due to increase in temperature or

(2) when the speed is decreased, since this decreases the rate of shear in the oil and when

(3) the load is increased.

The frictional force required increases with increase in viscous friction. The coefficient of friction is the frictional force divided by the pressure,

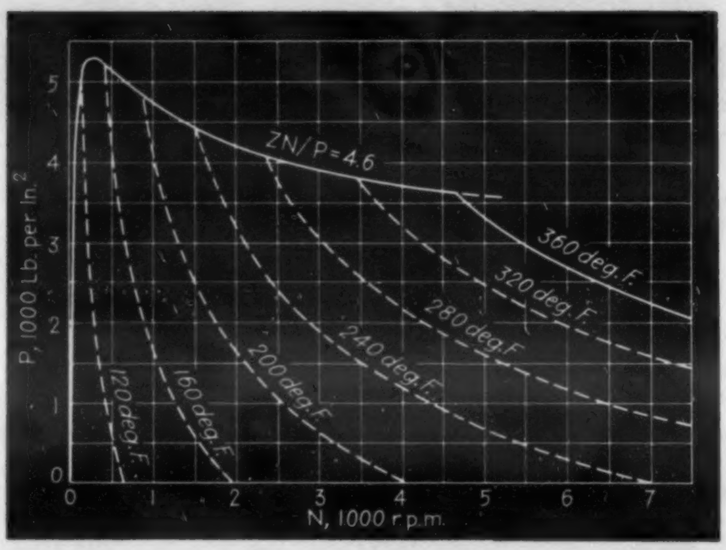


Fig. 3. Lines of constant temperature in region of stable lubrication. 2 x 1¼ in. test bearings; ambient temperature, 80 deg. F.; aviation oil 124.4 sec. SUV at 210 deg. F., 98 VI (S.A.E. 60) McKee[9].

therefore the coefficient decreases as the pressure increases.

When $\frac{ZN}{P}$ is plotted, the Z must refer to the *actual* viscosity of the oil under the ruling conditions, that is, if the temperature and hence the true viscosity of the oil differs when the values of N and P are changed, the coefficient of friction reflects not only the N and P changes, but the change in Z as well.

Viscosity of Oil

The viscosity of oil varies greatly with temperature, and it varies in different degrees with different oils. Some oils lose viscosity rapidly as temperature rises, others more slowly; they differ in "viscosity index."

It should here be pointed out that a certain $\frac{ZN}{P}$ relation holds only for any *one* bearing with a complete fluid film, but does not hold for other bearings of different diameters, clearance, and lengths. This fact has been brought out by Muskat and Morgan[1], who introduce the factors of clearance and diameter by plotting coefficient of friction times $\frac{r}{c}$ against $\left(\frac{r}{c}\right)^2$ times $\frac{ZN}{P}$ where r is shaft radius and c is clearance so that the generalized discussion may include the size factors.

Obviously, clearance is a necessity in a bearing, a press fit is not a bearing. If the clearance is too large, the bearing is loose and may "pound" or "chatter" under a varying load, and the oil leakage may be high. If it is too small, the friction will be high and some metallic contact may occur.

With the proper clearance, where the shaft starts to rotate, it lifts off the bearing, but does not become concentric with it. Instead of an annular ring, the clearance space is a circular wedge. The nip of the rotating shaft against the stationary bearing carries the oil through, just as the nip of rolling mill rolls carries a plate through the mill, or a wringer carries the clothes through its rolls. This pump action causes the oil to exert pressure against shaft and bearing, with the maximum pressure near the location of closest approach. Properly running bearings are essentially floating in oil. There may be negative pressure past the location of closest approach if the pressure at which the oil is supplied to the bearing is low, as the diagrammatic representation of the circumferential distribution of pressure, exaggerating the clearance space, shows in Fig. 1. Obviously, an oil inlet hole should be placed at the point of negative pressure, where the bearing is sucking, and not at the location of maximum positive pressure, where it would drain oil away from the point at which it is most needed.

There is no restraint at the edges of the bearing, so the oil is free to leak out, and the pressure falls there. Because of this side leakage, the supporting oil is a sort of pancake.

If leakage is prevented, so that the pressure of the oil wedge does not decrease to zero at the edges of the bearing, the load-carrying ability is increased, and the bearing will operate at low speed without breaking the oil film. [That is, the nose of the $\frac{ZN}{P}$ curve (see Fig. 2) may be brought down to a very low value.] A bearing designed to prevent leakage is used in roll neck bearings, of steel against babbitt, with the surfaces very true, the bearing being diamond bored, and with provision of an ample supply of clean oil.[2]

Effect of Oil Grooves

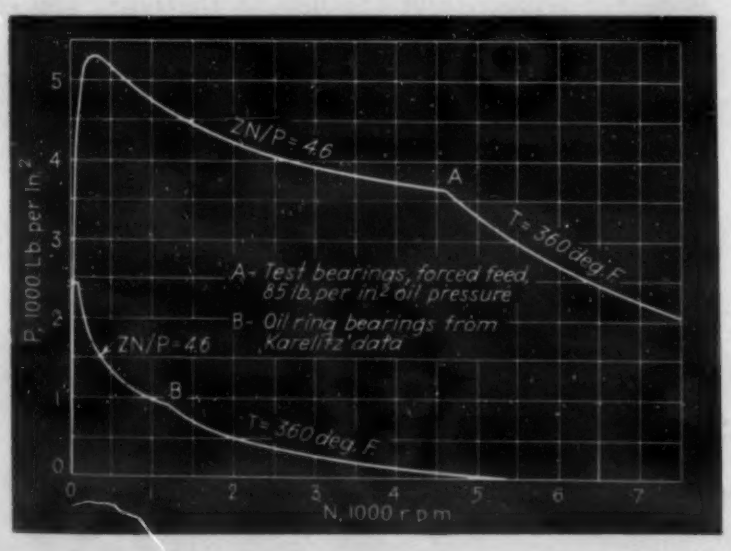
Oil grooves divide the big pancake into smaller ones, and unless very intelligently placed, tend to defeat, rather than to further the object of making the largest and strongest pancake. In similar fashion, a bearing of too small width in relation to its diameter, has too small a pancake. Much can be done by design to produce a good pancake and thus lighten the requirements on materials. This has been discussed many times. Forceful comments are given by many writers, e.g., by Falz[3], by Evans[4] and by Willi[5]. Such comments cannot be too forceful, for it is quite futile to claim a need for improved bearing metals when all that is really necessary is to avoid handicapping the available bearing metals by designs of oil grooves and locations of oil holes that break

up the pancake of oil instead of giving it its maximum possible size. Only when mechanical design gives the bearing metal a fair chance by eliminating unnecessary handicaps and the metal then cannot stand the necessary conditions of service, is it time to seek a better bearing metal.

As do all mathematical expressions of physical behavior, the $\frac{ZN}{P}$ relationship breaks down under certain conditions. In practice, bearings will rarely be found that operate under true fluid film lubrication for all periods of their use. Although bearings must operate under truly fluid film lubrication for the majority of their life if they are to give satisfactory service, there are times when they will not, and then the properties of the materials and the characteristics of the lubricant other than its viscosity become extremely important.

According to the fluid film theory of lubrication, it might be expected that a bearing operating at any speed, however low, or any pressure, however high, or with any lubricant regardless of how low its viscosity is, would be able to build up a lubricant film which will separate bearing and shaft and prevent metal to metal contact. In fact, the theory states that changes which give a thinner oil film give a lower coefficient of friction. Actually, since the film of lubricant at its narrowest point is very thin even under ordinary conditions, changing the conditions of operation so as to make the film thinner will bring the bearing and shaft so close that the theory, which considers the oil to be composed of infinitely small molecules and the bearing and shaft surface to be perfectly smooth and truly geometrical in shape, breaks down. In this region of operation, the effect of molecular size may enter, and such things as surface roughness, distortion, adsorption, grit, etc., must enter.

Fig. 4. Curves showing effect of change in heat-dissipation characteristics on permissible loads at various speeds. 2 x 1¼ in. bearings; ambient temperature, 80 deg. F.; lubricant, aviation oil 124.4 sec. SUV at 210 deg. F., 98 VI (S.A.E. 60) McKee[9].



Ideal and Actual Behavior

This region of lubrication is the one which deserves consideration from our point of view, and we now pass from the study of ideal behavior to the one which actually obtains at some periods in the life of almost every bearing. Here the properties of the materials are paramount.

For our purpose the real value of the $\frac{ZN}{P}$ way of expressing the interrelated variables is not so much in the region in which it holds, as in that in which it breaks down! This is brought out in Fig. 2, from Tichvinsky and Fischer[6]. The right hand portion of this graph shows that for a certain portion of the operating conditions, the $\frac{ZN}{P}$ relation does hold, since the friction decreases as the condition of operation (higher load, lower speed, lower viscosity) becomes more severe. However, instead of the curve continuing in a straight line down to the origin, the curve reverses and turns upwards at some low $\frac{ZN}{P}$ value. This minimum in the curve of friction is important, and largely defines the suitability of bearing combinations. To the left of this minimum, operation is unsafe, to the right good bearing performance is had.

As McKee[7] points out, "experimental data indicate that the minimum point of the f—$\frac{ZN}{P}$ curve may occur at $\frac{ZN}{P}$ values from 1 to 50, depending upon the kind of bearing metal, the machining of the bore and the amount of running-in." For this reason, Fig. 2 is not scaled.

Fig. 2 shows that (unless the pressure transmitted through the oil film to the bearing is so high that the bearing metal squeezes out at the operating temperature or cracks up by fatigue, or unless grit enters to disturb the fluid film) a bearing, once successfully brought into rotation at a high enough speed to establish a fluid film, is safe as long as it continues to run, though it may be injured in stopping. To keep away from dry friction, it is desirable to keep the shaft unloaded until it is in motion or to supply such high oil pressure that the shaft is lifted off the bearing before rotation starts. Both these means are actually used[8] in turbine and some analogous services, in order to avoid the break-down in the

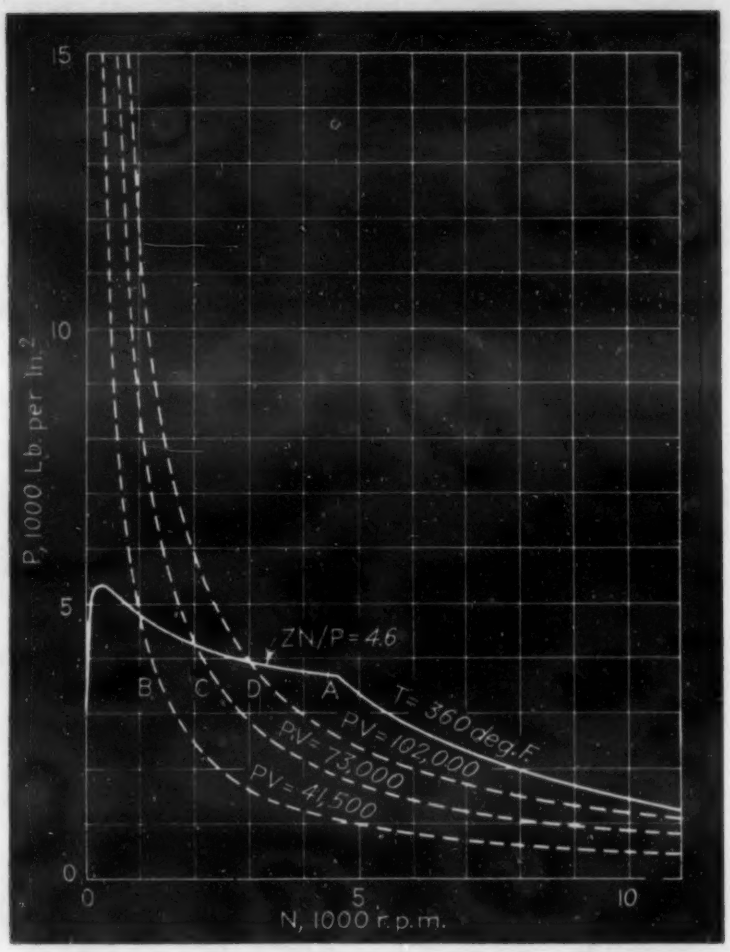
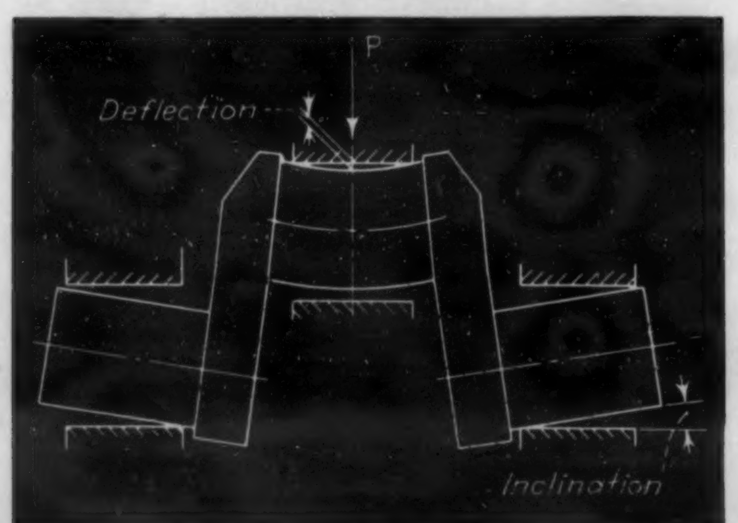


Fig. 5. Comparison between curves based on combined hydrodynamic and thermodynamic considerations and curves based on PV relation. 2 x 1¼ in. bearings; ambient temperature, 80 deg. F.; lubricant, aviation oil 124.4 sec. SUV at 210 deg. F., 98 VI (S.A.E. 60) McKee[9].

Fig. 6. Inclination and deflection of a laterally loaded journal. Falz[3].



$\frac{ZN}{P}$ curve at low speeds.

McKee[9] shows that it is possible to avoid semi-fluid lubrication under some conditions by the choice of proper oils. He found that on the basis of oils of different viscosities at 210 deg. F., the permissible pressures on a given bearing with force feed lubrication for *one speed,* 3500 r.p.m., are as follows:

Oil	Viscosity at 210 deg. F.—Centipoises	Permissible Pressures lbs. per sq. in.	Frictional Horsepower at 1000 lbs. per sq. in. Pressure	Bearing Temperature °F.
A	21.8	3,800	0.77	260
D	18.2	3,600	...	...
B	10.3	2,900	0.51	235
C	5.4	2,300	...	...

That is, the oil pancake will stand more load with the oil that is more viscous at operating temperatures, *but,* as McKee points out, between oils A and B, oil A will show 33 per cent greater frictional horsepower (power loss) and the bearing temperature (of the particular bearing assembly with the particular oil flow used) would be 25 deg. F. higher.

McKee also considers the use of these same oils at other speeds. Using oil A in this particular test bearing, as the speed increases the frictional horsepower increases and the temperature rises. McKee shows for a given pressure—2000 lbs. per sq in.—that at 7500 r.p.m. a bearing temperature of 360 deg. F. is reached, which is too high for stability of the oil.

By experiment, McKee found that for his particular bearing and for a particular oil, he could not reduce $\frac{ZN}{P}$ below 4.6 (in his system of notation) without breaking down the oil film. The heavy curve in Fig. 3 marked $\frac{ZN}{P}$ equal to 4.6 encloses the pressure-speed area in which complete oil films could be maintained, up to 360 deg. F. which he takes as the limit for his oil, while the dashed curves show the temperatures attained by the bearing surface under different conditions of pressure and speed. For example if the bearing metal used would not stand more than 280 deg. F., its range of applicability is bounded by that curve.

These curves are for an oil feed of some 85 lbs. per sq. in. and McKee points out that if less oil were supplied so that cooling was less efficient, the areas of permissible loading would shrink greatly. He brings this out strikingly in Fig. 4 in which he shows what would happen in his particular bearing, if, instead of forced oil feed at 80-85 lbs. per sq. in. the bearing had to depend on oil ring lubrication. Thus it is clear that the operating temperature of the bearing depends on the heat dissipation, both through the oil

supply and by conduction through the shaft, the bearings, and the bearing support.

The PV Curves

In practice, some engineers design bearings in relation to known bearings of good performance so that the known bearings and the new ones will operate at the same "PV," that is, that the product of pressure times velocity (in surface feet per minute) remains about the same. As McKee points out, this has worked, because the problem to be met by the new bearing is usually that of higher speed, and if the PV is held constant, there is an increase in the factor of safety with increases in speed, over the normal speed range.

It happens, too, that the PV curves, for a given bearing and given oil have much the same shape as the experimentally determined temperature rise curves for that bearing, as McKee shows by comparison of Fig. 3 with Fig. 5. Therefore, if the old bearing operated at a safe temperature, the new one probably will. However, it must be noted that the expectation of heating that would be drawn from Figs. 3 and 5, need not be realized, for one may cool one bearing more efficiently than another and thus decrease the temperature attained. Thus the PV approximation, as well as the $\frac{ZN}{P}$ relations, can both be altered materially by changes in the oil or the amount of oil supplied. They are lubrication features not directly related to the materials of shaft or bearing, yet the principles may frequently be applied to make substitute materials satisfactory.

For bearings of conventional types and normal heat dissipation it is possible to classify—as Willi[10] does in Table I—the permissible conditions of service on the basis of pressure, of $\frac{ZN}{P}$ of PV, and of temperature.

We want to keep the coefficient of friction low, but if, during the regular running of the bearing, we keep the coefficient so low (which implies being close to the nose of the curve f vs. $\frac{ZN}{P}$) that some slight disturbance throws the bearing behavior on the *incomplete* film branch of the $\frac{ZN}{P}$ curve, operation is unsafe.

Trueness and Smoothness

Trueness and smoothness of the shaft and bearing are also factors which can be applied to get more out of a bearing material. The theoretical concepts of fluid film lubrication are based on the idea that the shaft and bearing are perfectly smooth and true, not at all rough or out of round or conical, so that the wedge shaped clearance space in action is perfect. The actual bearing assembly falls short of this ideal.

Lack of stiffness in shaft or bearing, shown diagrammatically in Fig. 6 from Falz[3] results in "bell-mouthing" of the bearing by wear or by plastic displacement, so that there is proper fit between shaft and bearing only at one condition of loading; at all others the fit is not that contemplated by theory.

The effect of surface roughness may be shown by a series of experiments reported by Tichvinsky and Fischer[6] in which shafts of different hardnesses were operated against 2.5-in. diameter napkin ring bearings at 600 r.p.m. (400 surface ft. per min.) after having been "run in" for 8 hrs. The tests were made at low loads and with starved (slow drop feed) lubrication in an attempt to run close to the nose of the $\frac{ZN}{P}$ curve.

Table I. Field of Usefulness for Various Bearing Metals

Bearing Metal	Maximum Pressure, lbs. per sq. in.	Minimum Permissible $ZN/P_{max.}$	Maximum $P_{max.}V$	Oil Reservoir Temp. deg. F.	Minimum Crankshaft Hardness	Affected by Corrosion
Tin Base Babbitt Copper .... 3.50% Antimony .... 7.50% Tin ....89.00% Lead (max.) 0.25%	1500	15	42,500	235	Not Important	No
High Lead Babbitt Tin ....5 to 7% Antimony ....9 to 11% Lead ....82 to 86% Copper (max.) 0.25%	1800	10	40,000	225	Not Important	No
Cadmium-Silver Silver .... 0.75% Copper .... 0.50% Cadmium 98.75%	1800-3850	3.75	90,000 and upwards	260	250 Brinell	Not likely if temperature is maintained as specified and proper lubricating oil is used.
Copper-Lead Copper .... 60% Lead 40%	1800	3.75	90,000 and upwards	260	300 Brinell	

Shaft	Roughness of Shaft Microinches: Initial	Final	Coefficient of Friction: Starting	Running after 8 Hours	Temperature rise, deg. C.
Cr plated on 275 Brinell steel	44	25	0.45	0.055	..
Monel—330 Brinell	36	36	0.50	0.06	45
Nickel steel—217 Brinell	89	80	0.80	0.09	45
Free-machining steel—180 Brinell	133	89	1.10	0.13	54
Metal spray 1.20 per cent C steel on steel shaft of 275 Brinell	22	180	0.70	0.14	41

Other data were:	Coefficient of Friction: Starting	Running after 8 Hours
Cr plated shaft vs. tin babbitt	0.40	0.055
Cr plated shaft vs. 72% Cu, 9% Sn, 19% Pb	0.40	0.07
Cr plated shaft vs. 61% Cu, 1% Sn, 38% Pb	0.50	0.085
Cr plated shaft vs. silver	0.15	0.08

Running against a tin-base babbitt of 85 per cent tin, 10 per cent antimony, 5 per cent copper at 20 lbs. per sq. in. pressure with machine oil, the data above were obtained.

Starting and Running Friction

The starting friction increases with the roughness of the shaft and the running friction varies with the ease with which the shaft and the bearing wear in to a smooth finish. Statements in the literature that one bearing metal "has a lower coefficient of running friction" than another, need to be taken with a grain of salt. Experimentally it may be true that one bearing made out of one metal may allow operation at a lower coefficient of friction than another similar bearing made out of another metal, against the same shaft and with the same oil, but the difference is primarily due to the differences in the ease of securing comparable finishes, in the rate of wearing in of the bearing, in the behavior in presence of grit, in corrodibility, and so on. There should be differences in dry and semi-dry friction when starting and stopping, truly ascribable to the material, but observed differences between actual bearings are, in very great measure, due to differences in surface condition rather than to materials. These points are evident in the table above.

The wearing-in behavior as well as the effect of clearance has been discussed by McKee[11] in a series of papers. In these tests a $1\frac{1}{4}$-in. diameter tool steel shaft of 179, Brinell ground and lapped, was used against bearings of different compositions and clearances. The leaded bronze bearing was solid, the others were lined with 1/16-in. of white metal on a bronze back. The $\frac{ZN}{P}$ curve was obtained when the well-finished bearings were first installed, before wearing-in and from time to time for a period of about 17 to 75 hrs., depending on how rapidly they wore in. (See table below.)

The running-in initial and final $\frac{ZN}{P}$ curves for the leaded bronze, the soft tin babbitt, the lead babbitt and the alkali hardened lead are shown in Fig. 7. These bearings all had nearly the same clearance. The minimum of the $\frac{ZN}{P}$ curves for the initial state is the lower the softer the lining metal, but in the fully run-in condition there was no difference between the lead and tin base babbitts, while the alkali hardened lead and the leaded bronze had not yet come to as good a surface when the runs were stopped, nor did they reach quite as low a $\frac{ZN}{P}$ value.

The positions of the minima in the $\frac{ZN}{P}$ curves for all 6 tests are plotted against the frictional work done as the bearing wears in, in Fig. 8, which shows

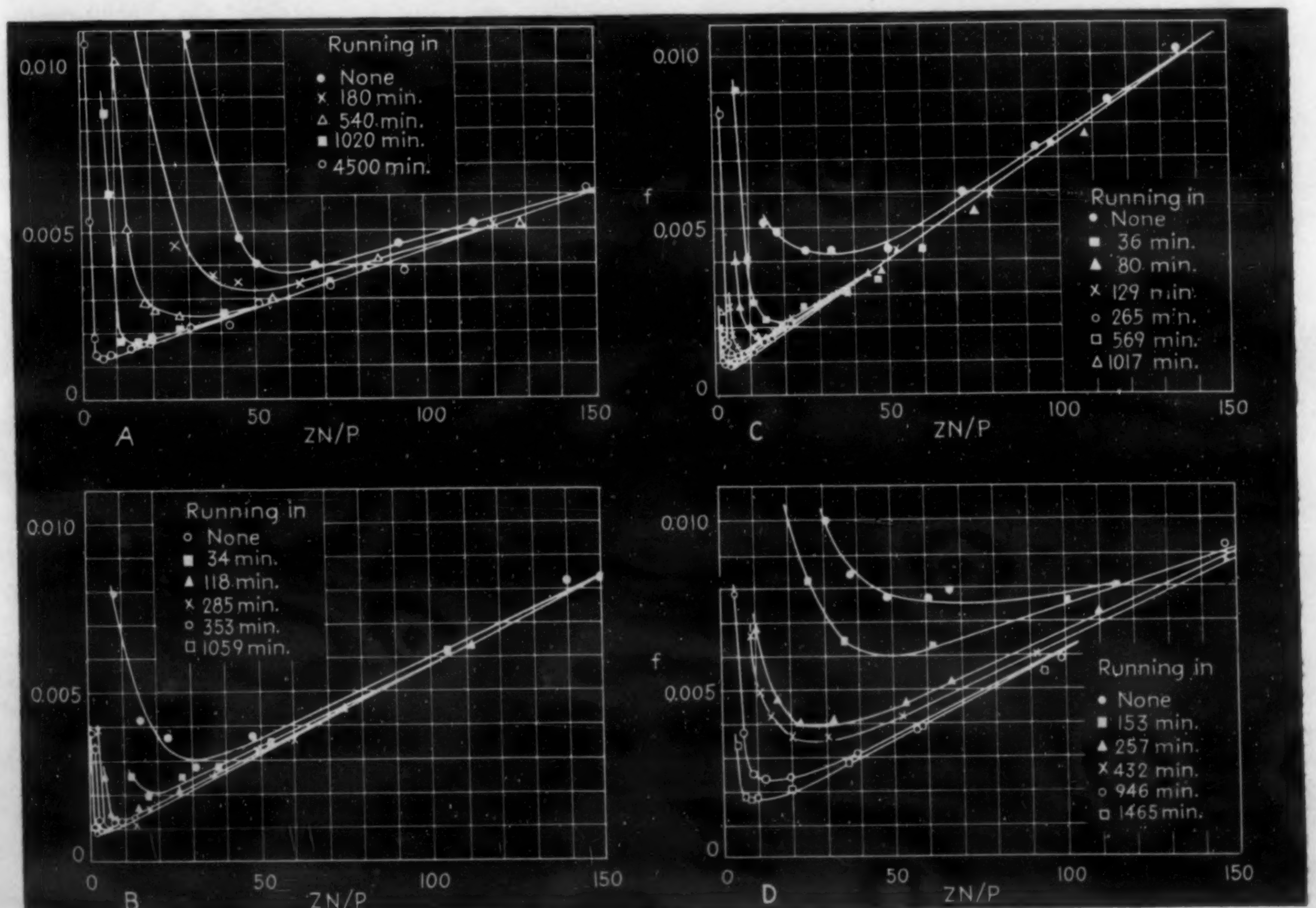
	Bearing Composition	Brinell Hardness	Clearance—Inches
C	Leaded bronze—72% Cu, 3% Sn, 25% Pb	..	0.0015 (against
3	Alkali hardened lead—97.5% Pb, 1.75% Ba, 0.75% Ca	26	0.0012 350
A	Hard tin babbitt—85% Sn, 7½% Cu, 7½% Sb	..	0.0027 Brinell shaft)
B	Hard tin babbitt—85% Sn, 7½% Cu, 7½% Sb	..	0.00056
1	Soft tin babbitt—90% Sn, 5% Cu, 5% Sb	19	0.0011
2	Lead babbitt—82½% Pb, 14% Sb, 3½% Sn	22	0.0010

that the soft tin and the lead base babbitts wore in very easily to low $\frac{ZN}{P}$ values, the hard tin babbitt with low clearance behaved much the same, while with large clearance (or perhaps with the hard shaft) it did not wear in so fast nor to such low $\frac{ZN}{P}$ values, while the hard alkali hardened lead and the leaded bronze acted much alike in refusal to wear in readily or to low $\frac{ZN}{P}$ values.

Karelitz and Kenyon[12] studied wearing-in from a slightly different point of view. They wanted to know whether thickness of the oil film wedge varied with different bearing metals, so a previously well worn-in steel shaft, hardness not stated, was run for 35 hrs. at 35 lbs. load upon flat slabs of 4 bearing metals under plentiful lubrication with SAE 30 oil. The shaft thus wore its own bearing, presumably with minimum clearance. At the end of the run, when conditions had become steady and the wearing-in period was practically over, the thickness of the oil wedge at its thinner end was measured at 124-130 deg. F., the temperature reached by the bearings. The results follow:

Bearing Material	Brinell Hardness	Oil Wedge Gap, In.	Nature of Worn Surface
89% Sn, 7½% Sb, 3½% Cu	22.3	0.00005	Eutectic worn away compounds in relief.
85% Pb, 10% Sb, 5% Sn	17.1	0.00006	Much like the tin base.
80% Cu, 8% Sn, 12% Pb	71	0.00005	Surface smeared and distorted.
70% Cu, 30% Pb	30	0.00004	Worn to rougher surface than the others.

Fig. 7. Journal friction curves, showing progressive amounts of running-in. McKee[11].



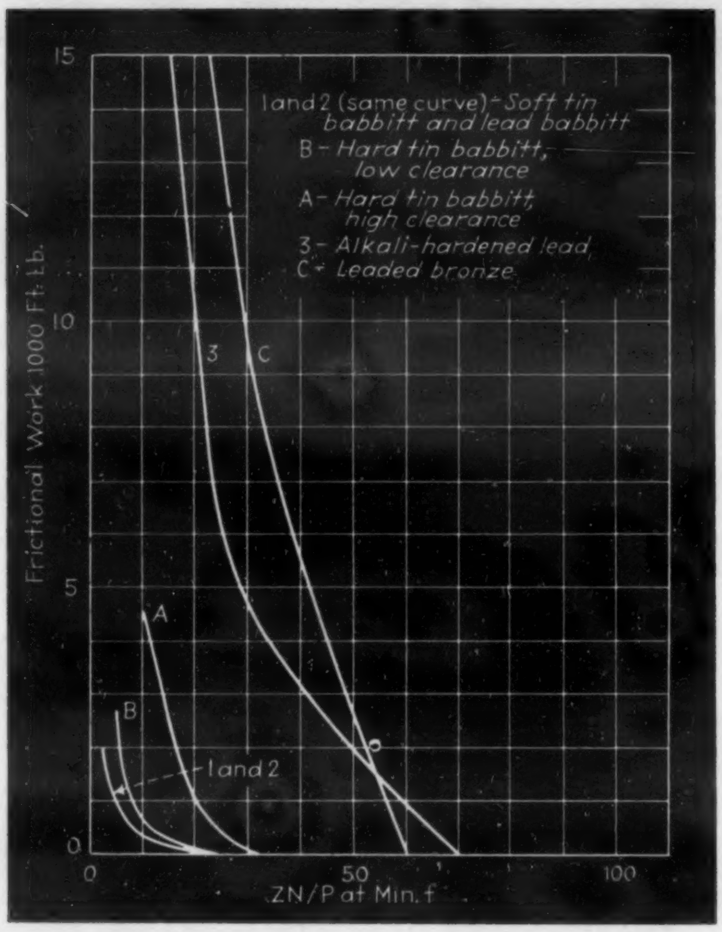


Fig. 8. Relation between location of the minimum point and the frictional work done on the various bearings. McKee[11].

1 and 2 (same curve): Soft tin babbitt and lead babbitt.

B. Hard tin babbitt, low clearance.
A. Hard tin babbitt, high clearance.
3. Alkali-hardened lead.
C. Leaded bronze.

Thus, the actual clearance required to permit the presence of a complete oil film is much less than the clearance of about 0.0010-0.0015 in. allowed in automotive bearings of normal size.

How Behavior is Governed

The data cited above from various workers show that while it is approximately true that after a shaft has picked up enough speed to pass the nose of the $\frac{ZN}{P}$ curve and has established full fluid lubrication, the behavior is governed by speed, pressure, viscosity of oil and by temperature, by bearing design and oil grooving and location of oil inlet, by clearance and by shaft and bearing roughness, by stiffness of shaft and bearing, all of which are, or can be, matters of design and dimensions without reference to materials, nevertheless a practical bearing is *not* insensitive to the materials used. Furthermore, the shaft has to start and stop. In starting and in stopping, when the oil film is too weak to support the shaft, the shaft tends to rub on the bearing. In these stages wear can occur, to different degrees, and to different degrees of harmfulness with different metals.

Even in the state where full fluid lubrication is supposed to hold in theory, and would hold if the oil were clean, grit in the oil can cut through the oil pancake and throw the bearing, locally, out of the condition of full fluid lubrication. Roughness of shaft or bearing, as has been discussed above, raises the nose of the $\frac{ZN}{P}$ curve and gives less margin of safety and a longer period of operation out of the fluid range in starting and stopping. The composition and hardness of shaft and bearing have much to do with the ease of preparing them in an initially smooth condition, and in allowing them to wear in easily to a still smoother state.

Since clearance is a factor, it would be expected that the thermal expansion of a bearing metal would affect its operation by affecting the running clearance.

Since temperature limits must be observed in order to avoid breakdown of oil, to say nothing of effects on the bearing itself, the thermal conductivity of the bearing assembly is important, and while the amount and temperature of the oil supply, acting as a coolant (See Fig. 4) and the way the design allows heat drainage away through the shaft and the bearing support, are more potent than choice of materials in regard to overall temperature of the bearing, yet the local temperature at the bearing face itself is probably notably affected by the thermal conductivity of the bearing materials.

Thin Lined Bearings

One more dimensional factor may be noted. The babbitt type bearing metals are not used in massive form as bushings, but only as linings upon harder, stronger, backs. Recent automotive practice has cut the thickness of babbitt linings down very far from those used in earlier practice, so that the backing exerts a distinct restraining effect against plastic deformation of a thin lining. This effect is well known in the case of glue, where a thin film makes a very much stronger joint than does a thick one.

The "anvil effect" in taking a Brinell hardness reading on a soft material resting on a hard backing is well known, and a very thin babbitt layer actually attached to a hard back gives a higher Brinell reading than a thick one does. Kühnel and Pusch[18] report for a babbitt of 79.2 per cent Sn, 11.6 per cent Sb, 6.7 per cent Cu, 2.5 per cent Pb on a bronze back:

Babbitt Thickness	2.5 mm. ball, 15.6 kg. load, 180 seconds	5 mm. ball, 62.5 kg. load, 180 seconds
0.02 in.	29.5	30.5
0.04 in.	28.6	28.6
0.08 in.	28.6	28.6

In a study of the shear strength of 56 per cent tin, 44 per cent lead solder, Nightingale[14] reports the following:

	lbs. per sq. in.
Shear strength, massive solder..	6,200
Maximum shear strength, soldered joint, copper to copper	0.001 in. thick 6,600
	0.002 in. thick 7,400
	0.003 in. thick 7,800
	0.004 in. thick 6,200
	0.006 in. thick 5,800

The decrease in strength below 0.003 in. may be due to the difficulty of getting a complete film of solder in the small gap, at any rate, at 0.003 in. the shear strength of the solder layer is 125 per cent of that of the massive material. Thus a bearing metal, too weak to stand the operating pressure in massive form may be made notably stronger by applying it in only a thin layer over a strong back.

Similarly Leach[14a] gives the following for joint strength of silver solder in butt joints of stainless steel:

Thickness in.	Strength lbs. per sq. in.
0.0015	over 130,000
0.003	115,000
0.006	90,000
0.010	80,000
0.020	55,000

The dimensional factors that are taken account of in the theory of fluid film lubrication, which hold irrespective of materials, and the other dimensional factors that come into the case, do *not* allow us to make a bearing out of any material whatever, because

(1) If the bearing will not stand the temperature we wish to impose upon it without permanent deformation, the dimensions necessary to the theory are not maintained;

(2) The actual bearing is not so smooth and true, nor is the oil as free from grit, as are implied in the theory;

(3) The bearing must start and stop, departing from conditions of full fluid lubrication, and in the starting and stopping periods different materials of construction do perform very differently; and

In the next installment we will consider the actual bearing as contrasted with the true and perfect bearing of theory, and the properties desired in bearings that are possessed by the alloys of tin whose substitution is to be studied, going on from there to evaluate some of the possible substitutes.

(To be continued)

References

[1] M. Muskat and F. Morgan. "The Thick Film Lubrication of Full Journal Bearings of Finite Width." *J. Applied Mechanics*, Sept. 1939, p. A117-A121.
"The Theory of the Thick Film Lubrication of A Complete Journal Bearing of Finite Length." *J. Applied Phys.*, Vol. 9, June 1938, p. 393-409.
"Experimental Coefficients for Thick Film Lubrication of Complete Journal Bearings." *J. Applied Phys.*, Vol. 9, Aug. 1938, p. 539-546.
See also: H. W. Swift. General discussion of Lubrication. *Proc. Inst. Mech. Engrs. (London)*, 1937, p. 385.

[2] J. H. Hitchcock. "Oil-flooded Bearings—Uses in Steel Rolling Mills." *Iron Steel Engr.*, Vol. 12, Nov. 1935, p. 14-15.
H. H. Wood. "Lubrication of Morgoil Roll Neck Bearings." *Iron Steel Engr.*, Vol. 14, Nov. 1937, p. 36-40.
W. Trinks. "Flood Lubricated Bearings." *Blast Furnace Steel Plant*, Vol. 22, 1939, p. 403.

[3] E. Falz. "Principles of the Design of Journal Bearings"—in General Discussion of Lubrication. *Proc. Inst. Mech. Engrs. (London)*, Vol. 1, 1937, p. 93-100.

[4] R. N. G. Evans. "Lubrication of Sleeve Bearings." *Product Eng.*, Vol. 6, p. 448-449; Vol. 7, 1936, p. 7-8, 57-58, 105-106, 109.

[5] A. B. Willi. "Engine Bearings from Design to Maintenance." *S.A.E. Journal*, Vol. 45, 1939, p. 513-523.
See also G. B. Karelitz. "Grooving Bearings in Machines." *Trans. Am. Soc. Mech. Engrs.*, Vol. 51 (2), 1929, M.S.P. 51-5, p. 22-28.

[6] L. M. Tichvinsky & E. G. Fischer. "Boundary Frictions in Bearings at Low Loads." *J. Applied Mechanics*, Sept. 1939, p. A-109—A-113.

[7] S. A. McKee. "Journal Bearing Design"—in General Discussion on Lubrication. *Proc. Inst. Mech. Engrs. (London)*, Vol. 1, 1937, p. 179-185.

[8] H. L. Guy & D. M. Smith. "Steam Turbine Journal Bearings." —in General Discussion of Lubrication. *Proc. Inst. Mech. Engrs. (London)*, Vol. 1, p. 115-121.
C. R. Soderberg. "Bearing Problems of Large Steam Turbines and Generators." *Ibid*, p. 285-295.
G. Welter and W. Brasch. "Tests of Plain Bearings with a New Method of Lubrication under Very High Pressure." *Ibid*, p. 330-335.

[9] S. A. McKee. "Friction and Temperature as Criteria for Safe Operation of Journal Bearings." *J. Research Natl. Bur. Standards*, Vol. 24, May 1940, p. 491-508. R. P. No. 1295.

[10] A. B. Willi. "How Materials Affect Plain Bearing Performance." *Machine Design*, 1940, p. 43-47.

[11] S. A. McKee. "Effect of Running-in on Journal Bearing Performance." *Mech. Eng.*, Vol. 49, 1927, p. 1135-1340.
S. A. McKee & T. R. McKee. "Journal Bearing Friction in the Region of Thin Film Lubrication." *S.A.E. Journal*, Vol. 31, 1932, p. 371-377.
S. A. McKee & T. R. McKee. "Running-in Characteristics of Some White Metal Journal Bearings." *Trans. Am. Soc. Mech. Engrs.*, Vol. 59, 1937, p. 721-724.

[12] G. B. Karelitz & J. N. Kenyon. "Oil Film Thickness at Transition from Semi-fluid to Viscous Lubrication." *Trans. Am. Soc. Mech. Engrs.*, Vol. 59, 1937, p. 239-246.

[13] R. Kuhnel & A. Pusch. "Die Prufung der Brinell Harte von dunnwandigen-Lagerausgussen aus Weissmetall." *Metallwirtschaft*, Vol. 18, 1939, p. 63-65.

[14] S. J. Nightingale. "Tin Solders," 1932, p. 28, 49.

[14a] R. H. Leach. "Low Temperature Brazing with Silver Alloys." *Iron Age*, Vol. 146, July 18, 1940, p. 36-39.

METAL DECORATIONS IN THE

"S. S. AMERICA"

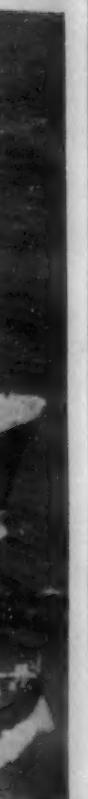
The use of certain metals and their alloys for decorative purposes such as murals, panels, doors, and miscellaneous applications is a strong trend in quite recent years. In our May and June, 1939, issues, we published two pictorial articles delineating the effect in the use of these materials at the New York World's Fair of 1939. Some of these applications were entirely new and definitely striking.

A more recent example of this trend is the new $17,000,000 United States luxury liner—the "S. S. America"—the largest vessel ever built by American shipbuilders. Its public inspection was held late in July in New York.

In some of the murals, doors, panels, railings, furniture, and so on, materials such as aluminum sheet, anodized aluminum (widely used), stainless steel, golden bronze, nickel bronze, copper, brass, and other metals and alloys are found artistically employed.

The pictures, reproduced here and furnished by the United States Lines, New York, give some idea of the highly effective and novel use of these materials.—E. F. C.

The dining room on the main deck. Hildreth Meiere, well known mural artist, has designed for this room four highly stylized and effective murals in metal depicting the skylines of San Francisco, New York, Paris and London. The background of these is chromium on glass, with a contrasting effect achieved by sand blasting and oxidizing to give the metal a velvety black appearance. The two visible here are San Francisco and the Golden Gate Bridge, whose copper suspension wires stand out strikingly, and London with the Houses of Parliament.



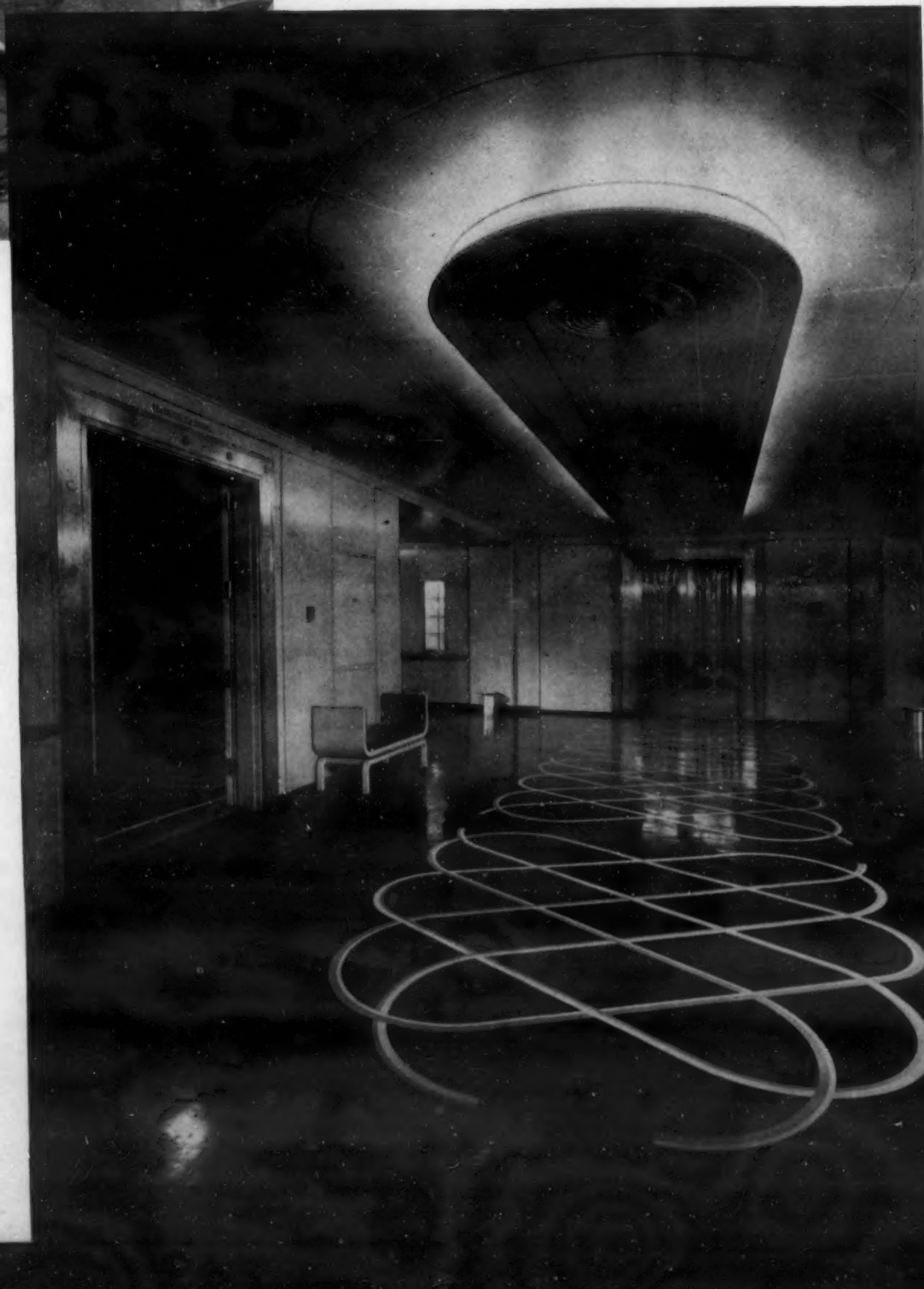
The swimming pool. The striking hammered copper ornaments are by Andre Durenceau, a leading American artist. The large metal mural of hammered copper represents leaping dolphins, shooting stars and seaweed; it is about 6 ft. high and 18 ft. wide, and is backed by deep blue glazed tile. It is gold plated and hand polished. The metal doors on the dressing rooms are also hammered copper (gold plated) and executed by the Sterling Bronze Co.

A map of the oceans of the world in the promenade deck foyer. It is made of sheet aluminum and is 11 ft. long and 4½ ft. high, and is in three sections—the work of Austin Purves, Jr. The continents are aluminum sheet, sanded and treated with caustic soda to give them a milk-white finish. The oceans are also aluminum sheet, but sanded and anodized to light slate gray.

Panels for the main stair wells—there are 26 of these—by Austin Purves. Twelve variants of the Zodiac signs have been used. These 18-in. sculptured figures in high relief are polished cast aluminum, and mounted on a rich red background. In all there are 213 pieces, buffed and anodized for protection against corrosion. The sun is in the center with the earth nearby.

Part of the library. A bronze group of leaping dolphins by Wheeler Williams can be seen on the commode. Metal table frames and metal ventilating grilles are used. The mural shows the development of the square sail from a spread skin to the towering American clipper ship. The lighting troughs here and elsewhere are mostly of aluminum and bronze.

A table in the principal dining room. A new design of stainless steel lamp is low so as to keep the light off the face. The murals are of carved lacquer.



Metal doors and frames. These on the promenade deck foyer are of golden bronze. In this and other metal doors the push bars are of nickel bronze. Some doors are made of nickel bronze.

The Iron Powder Situation

By Albert T. Fellows

Metals Disintegrating Co., Inc.
Elizabeth, N. J.

This review will be heartily welcomed by all those who for one reason or another are concerned about the continuity of supply, quality or price of iron powder. The ideal condition—a large and continuous supply of high quality iron powder at a low price—might give a powerful push to the application of powder metallurgy practice, but does not seem to be immediately attainable, even though many possible producers, as Mr. Fellows points out, are interested. The effects of the European war and the complicated inter-dependency of production capacity, price and demand are also revealingly discussed.

The author's viewpoint is obviously authoritative and evidently fair, but it cannot exactly be described as disinterested, since his company is one of the most active in the powdered metal field. Readers who may disagree with him on logical or factual grounds are invited, as always, to communicate their views to the editor for subsequent airing.—The Editors.

MOST METALLURGICAL ENGINEERS, particularly those associated with powder metallurgy, have heard an increasing amount of talk in recent months about powdered iron. This talk has been both of fact and of fancy. What American industry will do about iron powder, what powdered irons are available, what the future may have in store, and just how important iron powder really is, are timely questions, which this review will attempt to discuss.

Sponge Iron

Powdered iron in the form known as *ferrum reductum* has long been familiar to druggists and doctors as an honored member of the pharmacopoeia. Almost as many people have long known sponge iron, that more or less aggregated form of iron powder, which is (perhaps all too readily) obtainable by heating iron oxides with common reducing agents. Producing a little of this sponge iron is in fact so easy that it has led a long line of countless and intrepid souls into thinking that they were about to deal the blast furnace a knock-out blow and so be on the road to fame and riches. That their breed is not extinct can be seen by reference to almost any issue of the *Patent Gazette*. Indeed, the situation of past months has given them new encouragement and it would seem that up and down the breadth of the land iron ores are being heated with carbon, carbon monoxide, natural gas, hydrogen, and so on, and little bottles of the resultant iron powder are being taken out of vest pockets for inspection by potential investors, and by those seeking dependable sources of iron powder.

It should not be inferred that all these people have been impractical visionaries. Thus, the United States Steel Corp. ventured into the sponge iron field more than a decade ago with large scale experimentation at Lorain, Ohio, and at about the same time, the Ford Motor Co. was reported to have been more than interested in W. H. Smith's sponge iron ideas. Great interest in iron powder, while not new, has been given considerable impetus in the past months since Swedish iron powder has been denied access to this country.

As illustrative of the approach to this problem of what may be called the low-cost-iron-powder school, a special article in the April 10, 1939 issue of *Steel* may be mentioned. Presaged there was the early erection of domestic plants for economical production of iron powder. The essence of this type of reasoning, developed in that article, is that iron powder at 2 to 4 cents per lb. would lead to demand for 200 to 500 tons per day. It is not to be denied that metal powder at such low price would enormously stimulate powder metallurgy, even, perhaps, beyond the figures given. There is also no quarrel with those who foresee the situation so far in advance. The question is simply raised: How well founded are such speculations, and how much have they advanced the art?

Again, talk of sponge iron at this price, and even much lower figures, is not new. Bulletin No. 270 of the Bureau of Mines, issued in 1927, devotes some 175 pages to this subject. There one will find figures and accounts of actual production test runs, plans for commercial-size installations and cost estimates of from \$12.80 per ton for 100 tons a day to \$16.00 per ton for 20 tons of sponge iron per

day. One of the authors of this Bulletin writes in the Oct. 30, 1939 issue of *Steel,* reiterating the 1927 story, now directed particularly to iron powder. The point is mentioned here merely to call attention to what is undoubtedly an oversold idea, namely, that great advancement would automatically follow the availability of a very cheap iron powder, when, as and if such an iron appears. It is this idea that has been responsible for focusing attention of a large number of companies and individuals on the iron powder field. The sponge iron inventors who used to toy with the idea of supplanting the blast furnace are now about to revolutionize the powdered iron field. While the efforts of a limited number of these individuals or companies may be destined for commercial success, it looks as though many of them are doomed to failure.

The Demand for Iron Powder

As part of the development of that art known as powder metallurgy—the making of useful objects from powdered metals—articles made from powdered iron were not long in appearing. Small parts, especially those of an electrical nature, were the first and obvious ones—cores, magnets, etc. Small machine parts such as bearings, gears, and the like, were a logical development of ferrous powder metallurgy, aimed at reducing costs of the finished parts by elimination of expensive machining operations. On a test scale, much larger parts, such as automobile brake drums, and it has been heard, even whole engine blocks, have been made.

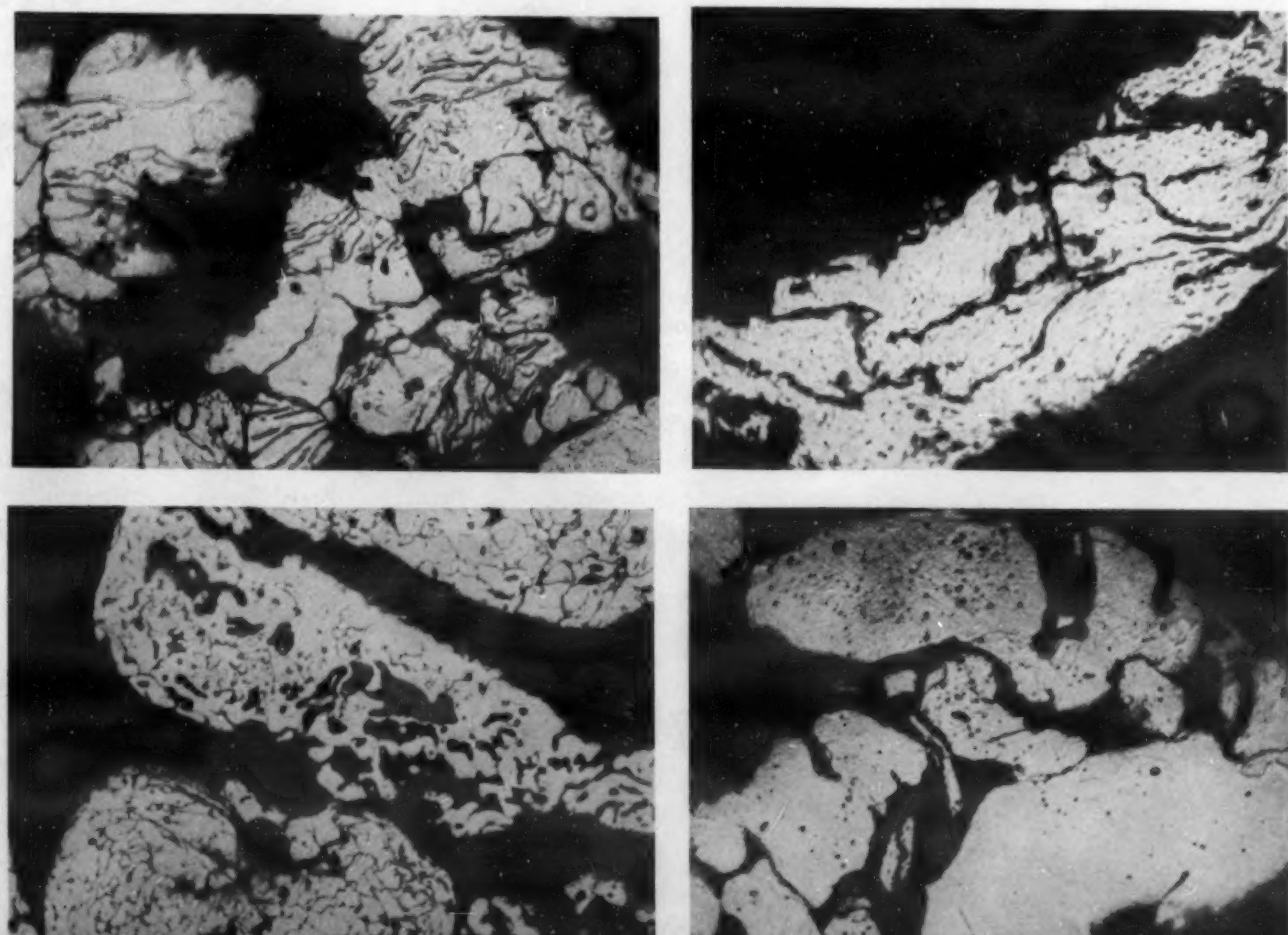
These types of use evolved on the basis of several varieties of iron powder of different qualities. There has been a limited number of electrical parts fabricated from the costly (about $1.00 per pound) iron powder obtainable by the decomposition of iron pentacarbonyl. Electrolytic iron and iron reduced from pure oxides by hydrogen reduction—irons of intermediate price, say in the range of 30 to 70 cents per lb.—have been most extensively used for applications of an electrical nature. Sponge iron—powdered reduced ore—has carried the bulk of the burden of supplying a material for the making of mechanical products. This sponge iron has been Swedish sponge almost to the exclusion of all else, because of the availability of the Swedish product at a price in the range of 7 to 10 cents per lb. The industry owes a debt to this Swedish powder because the major portion of the work suggesting the bright future of ferrous powder metallurgy has been carried out with this powder.

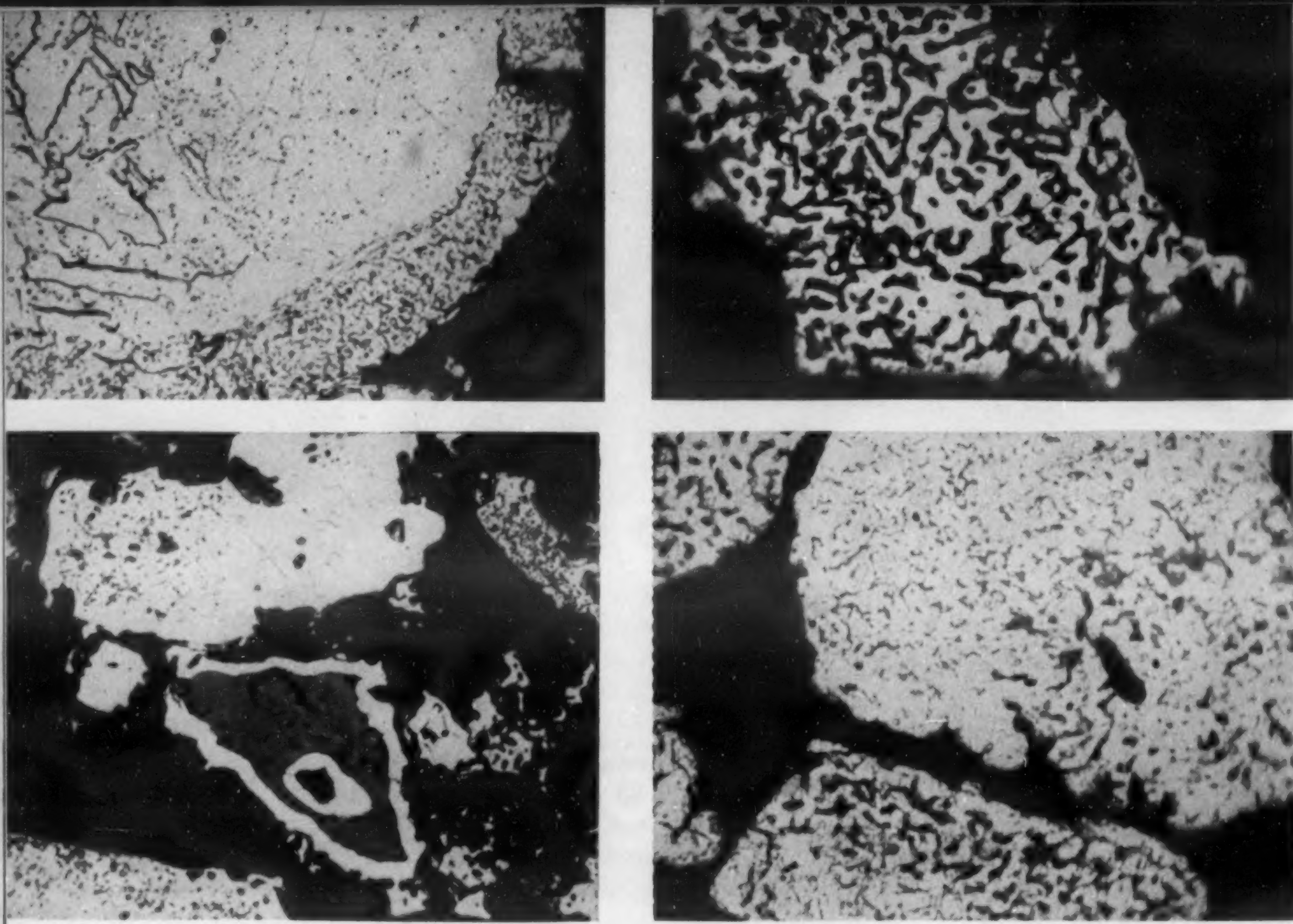
Tonnage possibilities for a sufficiently cheap iron powder have been mentioned above, but these figures are regarded as excessively high for the immediate and near future because iron powder of satisfactory quality at a price of 2 to 5 cents per lb. is not viewed as something that is just around the corner. Thus, limiting the discussion to the coming year, iron powder demand that is really insistent is considered to be about as follows:

(1) *Low cost iron*—iron for pressing and sintering into mechanical parts in competition with orthodox methods—is the field of greatest potential possibilities. The amount of powder required in this field will naturally be influenced by its cost. Thus, at 5 cents per lb., it would seem as though much more iron would be used than at 10 cents per lb.

It may not be quite so simple as this, however, without first specifying the quality of the powder. Thus, a 5-cent iron might be of such quality that the cost per particular finished piece made therefrom might be more than if the piece were made from a more suitable iron at 10 cents per lb. This is because pressing characteristics of the powder, wear on the expensive dies required, sintering costs, and size of finished piece required for a specific

Some commercially available iron powders as they look under the microscope (magnified 500X, etched with 2% nital): Top (a) Swedish sponge iron; (b) electrolytic iron; Bottom (c) and (d) other available iron powders.





Some experimental iron powders produced by various processes, photographed at 500X. All photomicrographs in this article were prepared by S. V. Wilson of Metals Disintegrating Co., Inc.

purpose might all be so much more favorable with a 10-cent iron than with a 5-cent iron as to dictate choice of the higher-priced product.

But if about 10 cents per lb. is taken as a likely starting figure, an iron powder of suitable quality, if it were available, might anticipate a present market of somewhere in the neighborhood of 1,000,000 to 2,000,000 lbs. (500 to 1,000 tons) for the year. Decrease in price from this figure, given usable quality, could be expected to bring new applications to the fore thereby increasing output proportionately.

(2) *Higher priced, better quality irons*—iron for the electrical type of use—is again a question of price vs. quality and will probably require several grades, one of which might be the low-cost iron just mentioned. In round figures, something of the order of from 600,000 to 1,000,000 lbs. (300 to 500 tons) could be sold during the coming year, at prices which would range from say 10 to 60 cents per lb.

Thus, no single iron powder will meet the needs of all users, and probably at least 3 grades of iron ranging from low to perhaps high priced will be demanded.

Effects of the War

The high-priced carbonyl iron of the German I. G. has been out of the American market for the past year. Swedish sponge, the low-priced iron, has likewise vanished from the scene. Electrolytic iron powder has been made commercially in the United States for a number of years and although the output is understood not to be large, no shortage of this grade of iron is apparent. Pure hydrogen-reduced irons also continue to be made domestically for those who require iron powder in this price range. In recent days, however, an established American producer of powdered metals appears to have emerged with quantity production of an iron apparently designed to approximate Swedish sponge powder in quality and price.

Prospective makers of iron powders must be vitally concerned with another factor that is not without interest to those who contemplate use of iron powder, namely, the war. Swedish sponge iron powder, the dominant factor in American ferrous powder metallurgy, passed out of the contemporary picture with the Norwegian campaign. It is not coming into this country at the date of this writing, but there is rumor that some sponge iron may soon get out by way of Petsamo, Finland. Incidentally, Swedish sponge iron may already have fulfilled its destiny in American powder metallurgy, inasmuch as its American importers have recently announced that a better and possibly a cheaper product would soon take its place.

In any event, there is still another way in which the war and Swedish sponge may affect the iron powder situation. British resistance to the Germans may remain so effective that Swedish iron continues to be denied access to the outside world, in which case the situation of the past few months, favoring establishment of an American iron powder industry, persists. But, if German successes to date are repeated in the days to come, German-dominated Swedish iron will be made available to the outside world as soon as the British blockade is broken. Its price, in that eventuality, would most certainly be a controlled price, not truly reflecting production costs.

If an American supply is not then available, an increase in price might be expected over the old figure. But, if an American process were establishing

itself, or had been established, Swedish iron could then be dumped at a price ruinous to the domestic producer, a situation analagous to the pre-*World*-War methods of the German dye combine. Which of these alternatives one wishes to choose or whether one feels the United States would be in a position effectively to combat violent trade practices of the type suggested are matters for the interested reader to decide for himself.

The company sponsoring this review, weighing the risks involved, believes it would be folly to attempt to bring out an iron which Swedish sponge could drive off the market if it were to return as a result of cessation of hostilities abroad. This conviction is based on research and development antedating Munich and not on a hurried job inspired by events of the past year. Iron powder produced as a result of *this* development will not be available in the customary thirty days or so that the industry must by now be coming to expect of forthcoming iron powder developments. This may also be the place to point out that just as some other metal powders were originally by-products or incidental to other manufacturing, sponge iron might also have been destined eventually to give way to a superior product made specifically for use in powder metallurgy.

Potential Iron Powder Producers

At least a score of individuals or companies appear to be more than casually interested in iron powder processes.

Activity of a number of these has been heralded in various announcements. The one established producer of electrolytic iron has announced an expansion program, and as noted above, another metal powder company is now marketing an iron powder in quantity. Most of the other developments, according to rumor, involve various types and kinds of ore reduction. Even great steel companies may be among those interested. Experimentally reduced sponge irons originating in Brazil have also been making the rounds for the past several years.

Several of these activities appear to be for a dual purpose; namely, to make raw material cheap enough to melt into steel and good enough to be satisfactory for powder metallurgy. So far, only the Swedes appear to have succeeded in this two-fold purpose, and it may be that the very special circumstances that made this possible will not repeat. Other developmental work, it would seem, is concerned with grinding of cast iron or other forms of iron such as chips, borings, and turnings, with reduction of mill scale, with atomisation of the metal, and so on. There is little indication of anyone's attempting first to make a quality product and then working to get its price down into the quantity range, which, by the way, follows the American tradition of progress.

The importers of Swedish sponge iron recently announced acquisition of rights to the Kalling-Rennerfelt process, and are apparently now engaged in modifying this process, which was originally developed for converting pig iron into a product of low carbon content suitable for remelting in steel furnaces. It involves granulation of molten pig iron by spraying into water, followed by decarburization of the so-obtained divided cast iron by use of a suitable gas mixture. Powder produced by this process, it is said, will soon be available. The price will be comparable to, if not lower than that of Swedish iron, and the quality superior. From the announcement, this superiority appears to be based on the greater densities of finished pieces made from this iron than those from sponge iron. Whether this higher density is truly representative of an improved quality remains to be seen.

Abnormally high pressures seem to have been used in making the test pieces from the modified Kalling-Rennerfelt iron. This appears to be related to the form of the iron powder, which might be expected to be substantially more or less solid pieces rather than spongy, porous pieces. High molding pressures result in increased cost of the finished piece, requiring not only larger, more expensive presses, but larger and more costly dies with decreased life. The volume of a finished piece vs. its weight also has to be taken into account. In short, iron powder of this type would seem to partake of the properties of an atomised product, and the writer's company, as a pioneer in atomised metals, might be presumed to have investigated similar methods of making an iron powder.

Mention of differing properties in powders prepared by various methods naturally recalls that no one material has universal properties and that the user will ultimately dictate which is the "best" material for his own needs. One thing is sure, the final decision will be made on the basis of overall cost of his finished article, rather than on the basis of the arbitrary price per pound paid for his raw material.

What is of peculiar interest to the writer in this age of progress and at a time when existence of opportunity is denied by many, is the fact that with fairly insistent demand over a period of time no completely satisfactory commercial solution of the iron powder problem has appeared. Considering the spread in properties, and in prices between spongily reduced ores and carbonyl iron, and considering the importance of, and the vast amount of work done on iron, it hardly behooves anyone to be more than humble when he ponders lines penned in 1650 by Joseph Glanvill:

> *"Iron seemeth a simple metal but in its nature are many mysteries . . . and men who bend to them their minds, shall, in arriving days, gather therefrom great profit not to themselves alone but to all mankind."*

Metals in Thin Layers

—Their Microhardness

by CHAUNCEY G. PETERS and FREDERICK KNOOP

National Bureau of Standards, Washington, D. C.

"Metallurgists will certainly be vastly interested in the new tool and in the data presented. We are very glad indeed to have the article."

This was the comment of our editorial advisory board when the article was passed on for publication.

The article is a description of the Knoop Indenter, a new instrument for determining the microhardness of thin layers of metals. One of the authors, Mr. Peters, has made hardness tests on a number of metallurgical materials that show the unique applications of this tool. Some of these were the determination of the hardness of the nitride skin on molybdenum high-speed steels, with different times and temperatures of salt bath treatments; the hardness of large carbide particles in high-speed and plain carbon steels; the hardness of sintered carbides, including boron carbide; and a number of other materials.—The Editors.

A SENSITIVE DIAMOND indenting tool has been developed recently at the National Bureau of Standards[1] for measuring primarily the indentation hardness of brittle materials such as glasses,[2] crystals,[3] and enamels[4] which shatter when tested with the ball, cone, or square-based pyramid tools commonly used on metals. The indenter is of pyramidal form having a diamond shaped base. Indenters of widely different angular shapes were studied and one was finally selected that produced an indentation having a length approximately seven times its width and 30 times its depth. The sensitivity of this tool is such that a load of 0.5 kg. gives for hard steel indentations of 100μ length which can be measured with an accuracy of 1μ with a micrometer microscope. It is evident from the magnitude of the penetration, which is but 3μ for an indentation of 100μ length, that very thin metal specimens may also be tested as well as brittle materials.

Some of the applications which we have made to thin sheet metals, nitrided layers, thin plating, and small particles in metallographic specimens are presented here with the hope that they may be of interest to those engaged in metallurgical work.

Diamond Based Indenting Tool

The indenter is a diamond crystal of 0.25 to 1.5 carats, rigidly mounted in a metal holder for cutting and use. The drawing to the left, Fig. 1, shows, schematically, the shape chosen because it best meets imposed conditions, and the drawing to the right (Fig. 1) shows the shape of the indentation. The sensitivity of this indenter results from its elongated shape which gives an indentation of length, l, that is seven times the width, w, and 30 times the depth, d.

The indentation or hardness number, I, is the ratio of the load, L, in kilograms applied to the indenter, to the unrecovered projected area A in $(\text{mm.})^2$

$$I = \frac{L}{A} = \frac{L}{l^2C}$$

in which l is the measured length in mm. of the long diagonal of the indentation and C is a constant relating l to the projected area. The indentation number corresponding to a measured length, l, and a given load can be read from a chart. From a measurement of the recovered width of the indentation an estimate of the elastic recovery can be gained.

Indenting and Measuring Apparatus

In making indentation tests, apparatus is required to apply a known load to an indenter for a definite contact period, and to measure the resulting indentations. The usual devices for making and measuring indentations are frequently incorporated in a single unit. Steps have been taken to make commercially

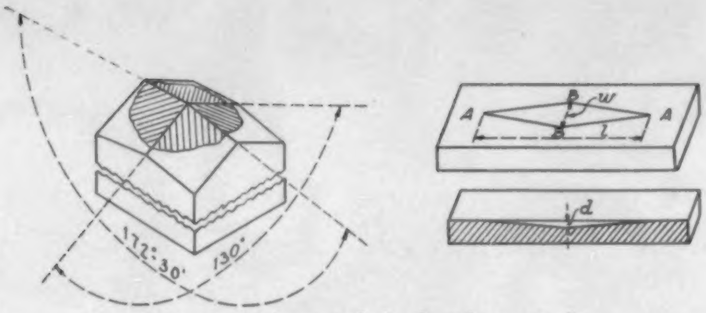


Fig. 1. Diamond indenting tool.

available equipment for using the pyramidal indenter.

For the present work the micrometer microscope equipment of the laboratory was used and the device shown in Fig. 2 for applying loads was designed and built. A calibrated lever arm carries a sliding weight, W. The arm is provided with pivot points near one end and carries the indenter, I, at its other extremity. A sliding and elevating specimen holder is shown at H. The indenter is raised to its correct position above the specimen by a cam and lever arrangement which lifts the piston rod, R, of the dash pot, P. The uniform rate of descent of I is controlled by a valve in P. The whole assembly is mounted on a base provided with levels and leveling screws.

Experimental Results

Chromium Plate: Nine steel gage blocks, 0.9 in. in diameter, 0.5 in. thick, were drawn to different temperatures and the surfaces polished plane within about 0.00001 in. The blocks were then plated with different thicknesses of chromium, deposited at different current densities by W. A. Olson of the Chemistry Division of this bureau. The plated surfaces were mottled and somewhat concave but a good plane polish was easily obtained on a tin lap with fine emery which removed about 0.00007 in. layer for the thick coats and somewhat less for the thin plate. Fig. 3a shows five indentations in the chromium plate using a load of 2 kg. and Fig. 3b shows for comparison five indentations in a Rockwell C25 test block using loads of 4 kg., 2 kg., 1 kg., 500 g., and 200 g.

The data obtained from the 9 samples of chromium plated gage blocks under loads ranging from 50 g. to 2 kg. are given in Table I. For platings of 0.001 in. or more in thickness, the hardness seemed to be unaffected by the hardness of the basis metal. Different current densities gave about the same results; if anything the lowest density seemed to produce a slightly harder plate. From an inspection of Table I it is found that the ratio of the plate thickness to the depth of penetration has a marked effect on the hardness number. Wherever that ratio became less than 14 for the heavier load, a marked falling off of the hardness ensued. From this, it is judged that to obtain consistent results, the plate thickness should be at least 14 times the depth of penetration of the indenter.

Phosphor Bronze Sheet: Nine samples of commercial phosphor bronze (Cu 95, Sn 4.6, P 0.2%),

TABLE I.—Hardness of Chromium Plate

Current density, amp. per sq. dm.	Cr Thickness, in.	I for Basis Metal	I for Plating					
			2 kg.	1 kg.	500 g.	200 g.	100 g.	50 g.
16	0.00007	600	...	603	616	618	656	700
16	0.00053	569	...	753	811	842	859	861
16	0.00100	446	...	721	823	840	893	876
16	0.00162	334	...	814	850	877	890	898
16	0.00195	262	738	833	850	884	928	909
25	0.00138	608	...	805	826	905	953	906
10	0.00107	600	...	853	877	916	920	896
10	0.00133	782	835	863	880	930	934	882
10	0.00267	780	831	874	890	902	897	898

Fig. 2. Microhardness apparatus.

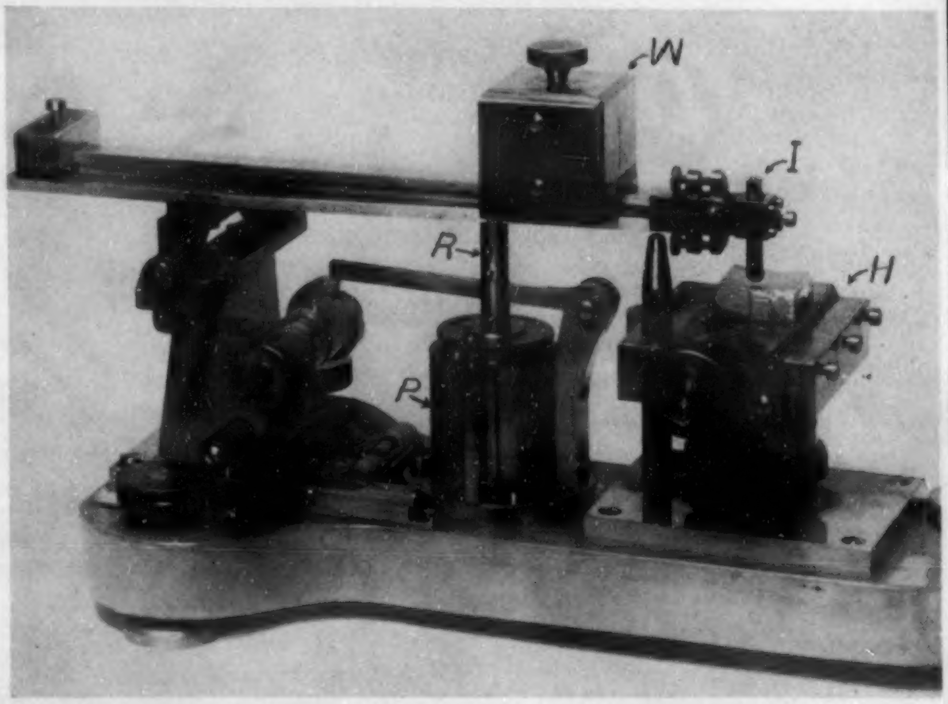
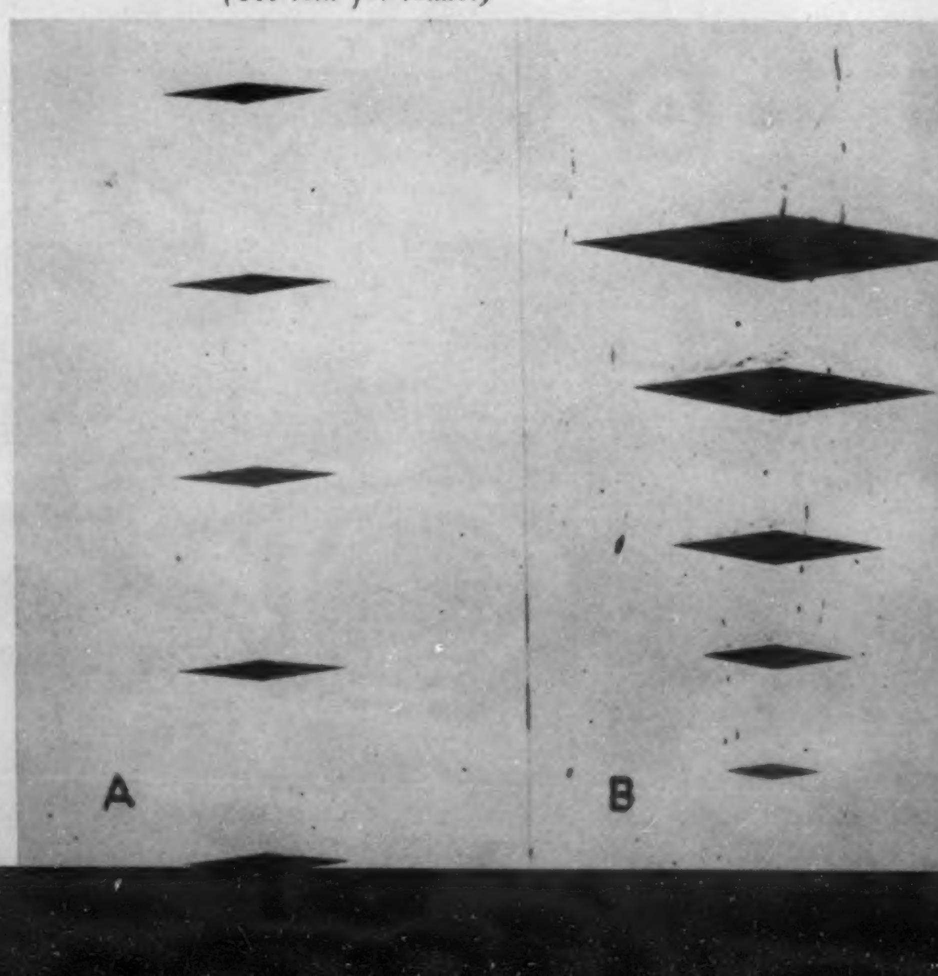


Fig. 3. (A) Indentations in chromium plate. 100X. (B) Indentations in Rockwell C—25 block. 100X. (See text for loads.)



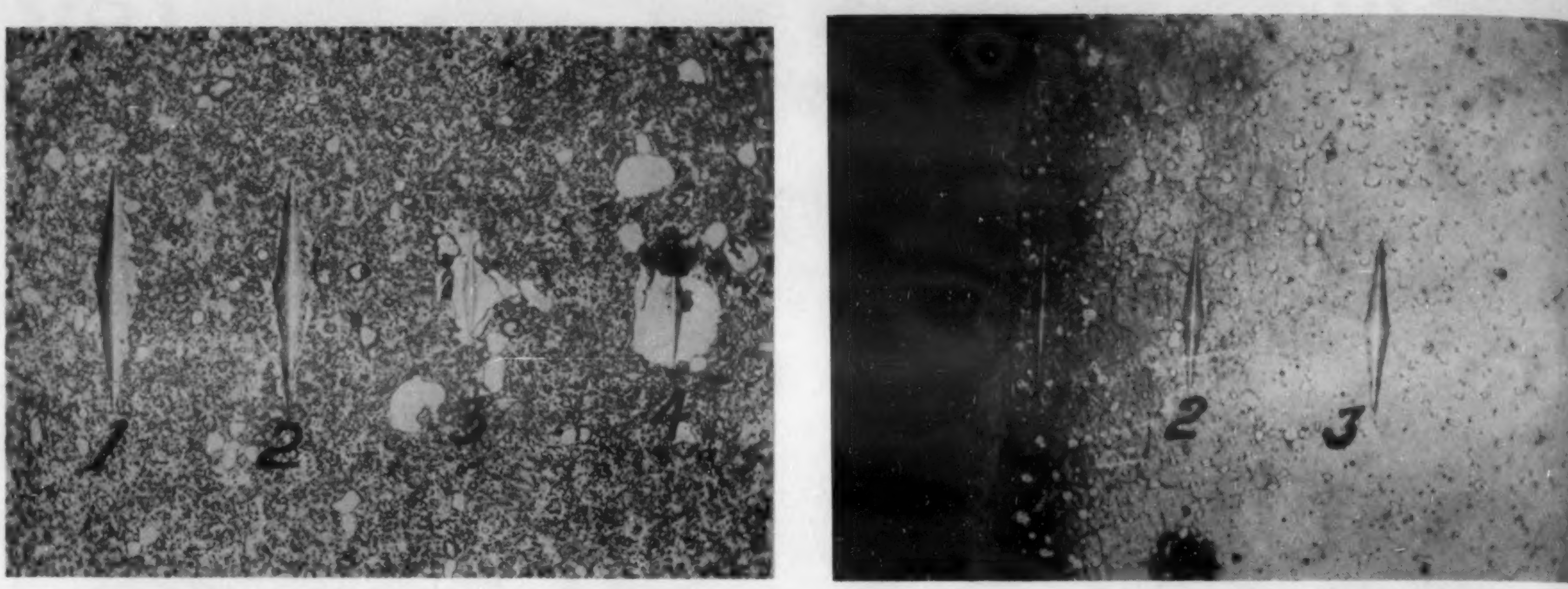


Fig. 4. (Left) Indentations in steel containing carbide particles 30 to 40μ in size. Numbers for the matrix 1 and 2 were about 240 and for the carbide particles 3 and 4 about 1430. 500X. (Right) Indentations in nitrided high-speed steel. Position 1 is 7μ; 2 is 40μ; and 3 is 80μ from surface. 500X.

rolled to thicknesses of from 0.002 to 0.008 in. were investigated. As in the case of chromium plate, the thin samples of phosphor bronze, Table II, gave low hardness numbers and for the heavy loads; the numbers decreased for thicknesses of 0.006 in. or less. With the 0.002-in. sample no difference in hardness was found for indentations having their long diagonal parallel and perpendicular to the direction of rolling. A marked softening of the last two samples was produced by heating to 400 deg. C. after rolling. For these the ratio of the necessary thickness to the penetration was about 35, while for the other specimens, it ranged around 25.

Carbides and Nitrided Steel: One annealed "EZ" and one hardened "EZ-45" specimen of molybdenum-tungsten-cobalt steel and one specimen "2778" of hardened molybdenum-tungsten high speed steel which had been nitrided by immersion for 2 hrs. in a bath composed of 50% KCN-50% NaCN at a temperature of 1030 deg. F. were furnished by R. G. Kennedy, Jr., Cleveland Twist Drill Co.

Figure 4a shows indentations made with a 50 g. load in the EZ annealed specimen. Indentations 1 and 2 in the matrix gave a hardness number of about 240 while 3 and 4 in the carbide particles gave a number of about 1430.

In Table III the numbers for three Rockwell C test blocks are included for comparison. For both the "EZ and EZ-45" specimens the hardness numbers for the carbide particles are practically the same while the number for the annealed matrix is 240 and for the hardened matrix 840.

Indentations made in the nitrided sample 2778, cut and polished perpendicular to the nitrided surface, are shown in Fig. 4b. Indentation 1 is 7μ, 2 is 40μ, and 3 is 80μ from the surface. The lower numbers at positions 4, 7, and 8μ from the edge,

TABLE II.—Hardness of Phosphor Bronze Sheet

Thickness in In.	I for Different Loads 500 g.	200 g.	100 g.	50 g.	
0.002	137	156	161	156	⊥ to rolling
0.002	139	159	165	162	‖ to rolling
0.002	142	157	165	...	
0.003	147	163	166	...	
0.004	166	173	186	...	
0.006	175	183	190	...	
0.006	177	180	181	...	
0.008	205	201	208	...	
0.004	67	84	92	98	Heated to 400 deg. C.
0.006	87	106	111	...	Heated to 400 deg. C.

TABLE III.—Hardness of Carbide and Nitrided Layer

Sample	I
Rockwell C 25	271
C 47	472
C 65–67	789
EZ Annealed	
Matrix	240
Carbide	1430
EZ-45 Hardened	
Matrix	840
Carbide	1460
2778 Matrix	785
Nitrided	
Distance from Edge	
4μ	680
7μ	725
8μ	865
10μ	1100
12μ	931
16μ	1108
17μ	1015
20μ	955
35μ	930
44μ	910
50μ	800
60μ	780

TABLE IV.

Set No. 1.—Annealed Samples Nitrided for Different Lengths of Time

Sam-ple	Nitrided Mins.	Nitrided Temp. deg. F.	Hardness for Loads 2 kg.	1 kg.	500 g.	200 g.	100 g.
0	0	1050	235	240	240	...	...
1	11	1050	307	373	457	572	667
2	31	1050	363	455	583	752	778
3	61	1050	449	584	704	829	855
4	121	1050	610	725	850	826	768
5	181	1050	718	765	768	698	647
6	241	1050	737	765	727	650	600
7	301	1050	717	701	654	596	552

Set No. 2.—Hardened Samples Nitrided for Different Lengths of Time

8	11	1050	833	871	898	947	996
9	61	1050	970	1042	1042	1080	...
10	121	1050	1018	1062	1067	1097	...
11	181	1050	1057	1097	1102	1114	...
12	241	1050	1067	1095	1097	1081	...

Set No. 3.—Drawn Samples Nitrided for Different Lengths of Time

13	0	1050	751	755	744	...	...
14	4	1050	827	871	886	926	860
15	11	1050	868	930	970	992	938
16	30	1050	981	1033	1051	...	...
17	90	1050	1057	1124	1110	...	...
18	300	1050	1078	1085	1103	1077	1034

Set No. 4.—Drawn Samples Nitrided at Different Temperatures

24	0	850	752	786	779	753	747
25	30	850	776	814	847	838	844
26	0	950	...	810	822	...	...
27	30	950	881	948	1004	1061	1104
28	0	1000	769	798	809	812	802
29	30	1000	944	1007	950	933	878
30	0	1150	...	744	747	...	...
31	30	1150	930	990	1021	1015	1023
32	0	1250	598	603	612	592	606
33	30	1250	817	872	873	924	920

Set No. 5.—Hardened Samples Nitrided at Different Temperatures

34	31	900	830	860	868	905	900
35	31	950	834	881	909	925	991
36	31	1000	859	954	1012	1048	1044
37	31	1050	908	959	1033	1070	1100
38	31	1100	963	1027	1044	1020	1030

Table III, resulted from partial cracking at the outer side of the indentation.

At depths from 10 to 20μ, the maximum hardness was found; beyond 20μ the numbers decreased until they became constant at the matrix value for depths greater than 60μ. This shows that the effect of the nitriding reached a depth of about 0.002 in. and was a maximum to a depth of about 0.001 in.

Nitrided High Speed Steel: The data shown in Table IV were obtained from specimens of nitrided 18-4-1 high speed steel furnished by J. G. Morrison of the Landis Machine Co. and J. P. Gill of the Vanadium Alloys Steel Co., who recently presented the results of their investigation of nitriding this type of steel.[5]

The different sets of specimens were annealed or hardened and drawn before nitriding and the individual specimens of a set were nitrided for different periods of time or at different temperatures. All the samples were micropolished before nitriding except the specimens of Set No. 4 which were lapped before and micropolished after nitriding. The data given here are presented to demonstrate simply that the pyramidal indenter will measure the difference in hardness produced by the different nitriding treatments. Consequently no attempt is made to discuss the metallurgical phases of the subject.

The samples of Set No. 1 were annealed and of Set No. 2 were hardened, but not preheated before nitriding, and then immersed in the bath at 1050 deg. F. for periods of time ranging from 11 to 301 mins.

These data show that the final numbers of the hardened samples are much higher than those of the annealed samples. The increase in hardness, however, produced by the nitriding is greater for the annealed samples.

The data of Set No. 1 show the same effect of lower hardness numbers for thin layers and heavy loads that were found for thin plating and rolled sheets. The 11 minute nitriding produces a layer approximately 0.0005 in.; the 30 mins., 0.001 in.; and 60 or more minutes, 0.002 in. thick. It is estimated that here the necessary ratio of thickness of the layer to depth of penetration is between 6 and 10 to 1.

The specimens of Sets No. 3 were hardened and then drawn to about Rockwell C 64 hardness. The nitriding was done at 1050 deg. F. for time intervals ranging from 4 to 300 mins.

The samples of Set No. 4 were hardened and drawn to Rockwell C 64 and 5 were nitrided for 30 mins. at temperatures from 850 to 1250 deg. F.

Fig. 5. Microhardness of decomposition products of a grain of austenite of high-purity iron-carbon alloy containing 1.14 per cent C. Etched with 1 per cent nitric acid in alcohol. 350X.

Position	Micro-hardness No.
1	260
2	475
3	690
4	570
5	720
6	725
7	425
8	300
9	190

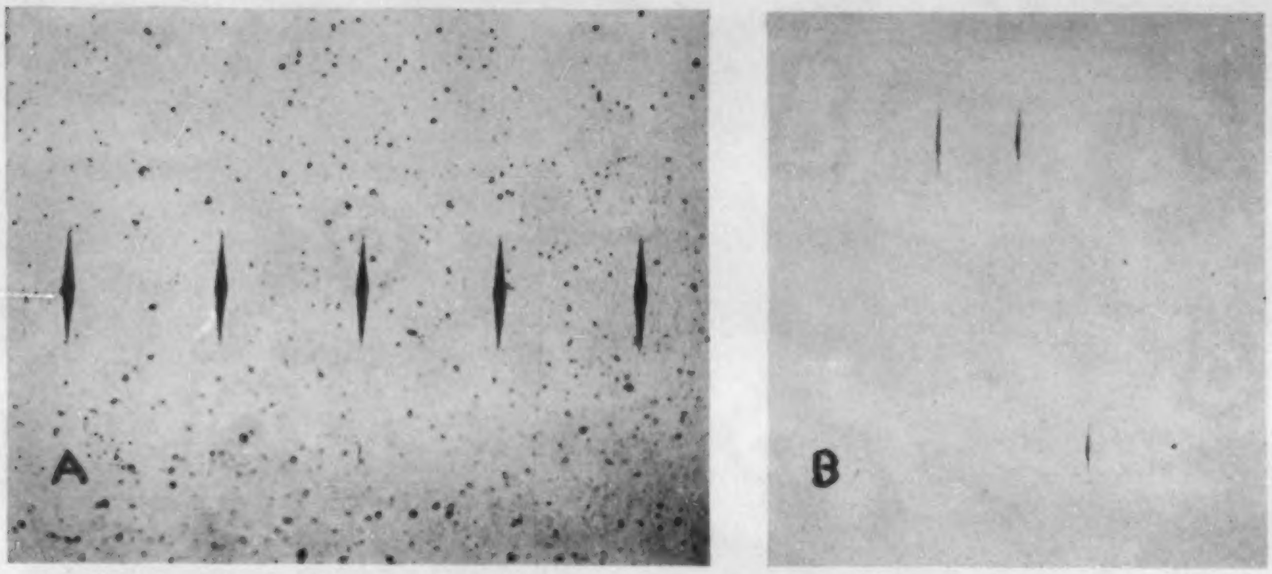


Fig. 6. (a) Indentations in molded boron carbide. 250X. (b) Indentations in polished diamond. 250X.

Companion samples were heated in the preheat furnace to the same temperatures as the nitrided mate. The hardness of samples nitrided at the lower temperatures and at 1250 deg. F. is much lower than for those nitrided at temperatures near 1000 and 1150 deg. F.

For Set No. 5 the samples were hardened and then nitrided for 31 mins. at temperatures from 900 to 1100 deg. F. When measured with the heavy loads, the highest hardness was produced by the 1100 deg. F. nitriding.

From an inspection of all the data in Table IV, it appears that nitriding for about 90 mins. near 1100 deg. F. should produce the maximum surface hardness.

Metallographic Sample of Iron-Carbon Alloy: Fig. 5 shows indentations in the different constituents of a metallographic specimen of high purity iron carbon alloy prepared by T. G. Digges[6] of the Metallurgy Division of this Bureau. Indentations 1 to 9 were made with a load of 100 g. while those near the left edge of the figure were made with a load of 50 g. The nodule of troostite 25 to 30μ in diameter (position 4) had a hardness number of 570 whereas the surrounding martensite (positions 3, 5, and 6) had a value of about 700. Determinations of the hardness were also made in the coarse grain of lamellar pearlite both transversely (position 8) and in the direction of the laminations (position 9).

The results show that the pearlite grain was apparently softer in the direction of the laminations.

The interesting feature brought out by the microhardness test was the wide variation in values obtained for the decomposition products of one grain of austenite, although the cooling rate must have been uniform throughout the entire grain. The hardness values determined ranged from about 190 for the soft pearlite to about 720 for the fully hardened martensite.

Comparison of Brinell, Vickers and I Numbers: Indentation numbers were determined for several standard specimens with the pyramidal indenter, and the Brinell and Vickers hardness machines. In Table V the indentation numbers I are 20 per cent greater than the corresponding Brinell numbers for sheet copper and agree with the Brinell numbers for steel C 65-67. Numbers I are 13 per cent greater for sheet copper and 12 per cent less for steel C 65-67 than the corresponding Vickers numbers. In view of the differences in the shapes of the indenters and the bases of computation, these differences in the numbers could well be expected.

TABLE V.—Comparison of Indentation Numbers I and Brinell and Vickers Numbers for the Same Specimens

	Conditions of Test				
Specimen	Ball	Load (30 sec.), kg.	Brinell Number	Vickers Number	Indentation Number, I
Rockwell C 65-67.	10 mm., Carboloy	3000	780	894	791
Gage No. 2......	10 mm., Carboloy	3000	745	848	779
Gage No. 1......	10 mm., Carboloy	3000	611	655	637
Rockwell C 47...	10 mm., Steel	3000	456	493	496
Rockwell C 25...	10 mm., Steel	3000	241	265	276
Rolled Copper...	1/16 in., Steel	15	104	111	125
Rockwell B 7-9..	10 mm., Steel	500	52.8	58.2	59.2

Minerals and Abrasive Materials: The hardness numbers for minerals of the Mohs scale, and for several hard abrasive materials are given in Table VI. The abrasive materials alundum, silicon carbide and boron carbide were furnished by R. R. Ridgway

TABLE VI.—Hardness of Mohs Minerals and Abrasive Materials

Samples	I
Gypsum	32
Calcite	135
Fluorite	163
Apatite ∥ to axis	360
Apatite ⊥ to axis	430
Albite	490
Orthoclase	560
Crystalline quartz ∥ to axis	710
Crystalline quartz ⊥ to axis	790
Topaz	1250
Carboloy	1050–1500
Regular Alundum No. 1	1635
Regular Alundum No. 2	1625
Regular Alundum No. 3	1620
98—Alundum No. 1	1670
98—Alundum No. 2	1680
Black Silicon Carbide No. 1	2150
Black Silicon Carbide No. 2	2050
Green Silicon Carbide No. 1	2130
Green Silicon Carbide No. 2	2140
Molded Boron Carbide No. 1	2250
Molded Boron Carbide No. 2	2260
Molded Boron Carbide No. 3	2250
Diamond	8200–8500

of the Norton Co. The minerals obtained from several sources were optically clear specimens. The numbers are the average of several determinations made on one or more specimens which in some cases differed appreciably. These results show that a big gap exists in the hardness scale between the hardest carbides and the diamond.

Fig. 6a shows five indentations made with a 500 g. load in molded boron carbide. Clear indentations similar to these were obtained with the other abrasive samples and the point of the indenter showed no wear or injury. Fig. 6b shows three indentations made with a 1 kg. load in the polished surface of a clear octahedral diamond.

In making these tests on the diamond, we found that the points of indenters having the small included angle from 112 to 126 deg. shattered before making a visible indentation on the plane surface. On increasing the indenter angle to 136 deg. the point stood the 1 kg. load and indented the plane diamond surface as shown in Fig. 6b. Under these latter conditions the results indicate that the point under compression is stronger than the plane surface in tension, since both point and sample were clear crystals from the same lot.

The extremely high force exerted by the minute point of the diamond tool in making the indentations in these hard materials may be better appreciated when expressed in pounds per square inch, rather than in kg. per sq. mm. For hardened steel, the pressure computes to be over 1,000,000 lbs.; for the molded boron carbide over 3,000,000 lbs.; and for the diamond about 12,000,000 lbs. per sq. in.

References

[1] F. Knoop, C. G. Peters, W. B. Emerson. *J. Research, Natl. Bur. Standards,* Vol. 23, July 1939, RP 1220.

[2] C. G. Peters, F. Knoop. *Glass Ind.,* Vol. 17, May 1936, p. 153.

[3] C. G. Peters, F. Knoop. *Glass Ind.,* Vol. 20, May 1939, p. 174.

[4] G. C. Paffenbarger, I. C. Schoonover, W. S. Souder. *J. Am. Dental Assoc.,* Vol. 25, Jan. 1938, p. 74.

[5] "Introductory Study of the Nitriding of Hardened High Speed Steel by the Use of Molten Cyanides." J. G. Morrison & J. P. Gill. *Preprint, Am. Soc. Metals,* Oct. 1939, 76 pages.

[6] T. G. Digges. *J. Research, Natl. Bur. Standards,* Vol. 23, July 1939, p. 151, RP 1225.

A Couple of Chuckles

A Chuckle and A Correction

We have been advised, and with some justification, that the Letter to the Editor, July issue, page 54, "Uranium and Its Isotrope, U 235," should have been published as a Chuckle—of course, because of the spelling of Isotope with an *r*!

We find that the author of the letter spelled the word correctly in his copy and that the typed copy that went to the printer also had the correct spelling. Our editorial director, in commenting on the letter, characterized it as "an awful bull" and said, "we are not reverting to unsimplified spelling!"

Imagine the editor's chagrin when he saw this mistake! There is no excuse for such an error which should have been caught in proof-reading (probably the proof-reader does not know *Isotope* from *Isotrope*). We still do not know how the letter r was introduced—one of the strange things that happen in this publishing business!

Our readers have our apologies.—E.F.C.

"White Hot Metal at 300 Deg."!

For a "chuckle" I nominate the temperature at the top of page 136 of the May issue of METALS AND ALLOYS—"white hot (300 deg. F.) metal."

J. T. MACKENZIE

Calling this to our attention is not unexpected. It is another of those "typographical errors" which unfortunately disconcert an editor now and then. Fortunately the caption of one of the illustrations was correct at 3,000 deg. F.—The Editors.

Letters to the Editor

Failure of Low-Carbon Steel Still Tubes

To the Editor: The examples of intergranular failures in both low carbon and low carbon plus 0.50 per cent Mo still tubes presented by Dr. Moore in the April issue, page 123, are about the first of this kind to be publicized in the literature. I agree with Mr. Wright's comment that these fractures are of the creep to rupture type.

Several years ago this type of fracture was experienced with the use of low carbon steel for mercury boiler tubing at temperatures in excess of 1000 deg. F. The occurrence of these brittle appearing fractures was especially alarming as the fractures usually took place with little or no warning. After many rupture tests on plain carbon and low alloy steels had been made, it was found that identical fractures could be produced in the laboratory, and the conclusion was reached that there was nothing unusual about the occurrence of this type of fracture. In fact, laboratory rupture tests on many types of alloys have indicated that, in the 900 to 1300 deg. F. temperature range, only the chromium bearing ferritic type alloys, with additions of at least 5 per cent chromium, will show complete freedom from failure by intergranular cracking in tests of long duration. The amount of elongation accompanying long time fractures varies appreciably, however, with the alloy compositions, and in some instances is as large as if the fracture had been of the ductile, transcrystalline type.

Mr. Wright's statement, that "We know now that in conventional tensile creep testing, if the stresses are high, nonductile fractures can be developed," intimates that only high values of stress will produce intergranular fractures. Of course, whether the fractures are transcrystalline or intergranular it must be accepted that the stress was in excess of the long time rupture strength of the material at that temperature. Otherwise, failure would never have occurred. But rupture tests indicate that the most brittle fractures result from tests of long duration where lower stresses are employed. In fact, with the application of exceedingly high values of stress that approach the short time high temperature tensile strength of the material, ductile transcrystalline fractures usually result. Since higher temperatures and lower strain rates are known to favor the occurrence of intergranular cracking of metals, it seems most likely that the fractures presented by Dr. Moore are due to increased temperature rather than to increased stress.

Some recent rupture test results at 1000 deg. F. on two low carbon steels, one killed and the other rimmed, lead one to believe that steel mill practice may also affect the susceptibility of carbon steels to failure by intergranular cracking at elevated temperatures. The two materials were produced in the same mill, had the same heat treatment, and were very similar in composition. The results, although somewhat meager, indicate clearly that the killed steel was more susceptible to failure by intergranular cracking than was the rimmed steel. The compositions of the two materials are as follows:

	Killed Steel Per Cent	Rimmed Steel Per Cent
Carbon	0.17	0.15
Manganese	0.43	0.46
Phosphorus	0.020	0.020
Sulfur	0.030	0.030
Silicon	0.19	trace

Both materials were hot rolled and annealed at 1560 deg. F. and had the following physical properties at room temperature:

	Killed Steel	Rimmed Steel
Ultimate strength, lbs. per sq. in.	66,400	61,400
Yield point, lbs. per sq. in.	45,100	45,400
Reduction in area, per cent	64.6	64.7
Elongation in 2 in., per cent	36.5	39.0
Brinell hardness	126	111

The structure of the two materials as tested are shown in Figs. 1 and 2.

At 1000 deg. F., rupture test results on the two materials were as follows:

Fig. 1. Structure before testing of killed 0.17 per cent carbon steel. X250.

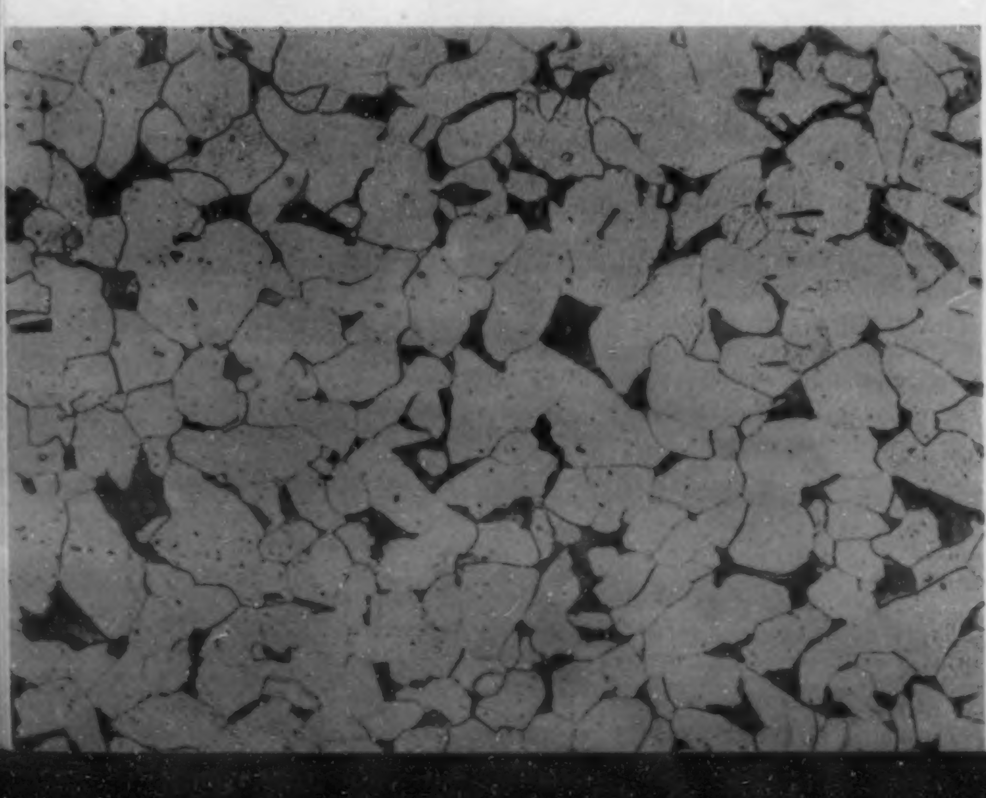


Fig. 2. Structure before testing of rimmed 0.15 per cent carbon steel. X250.

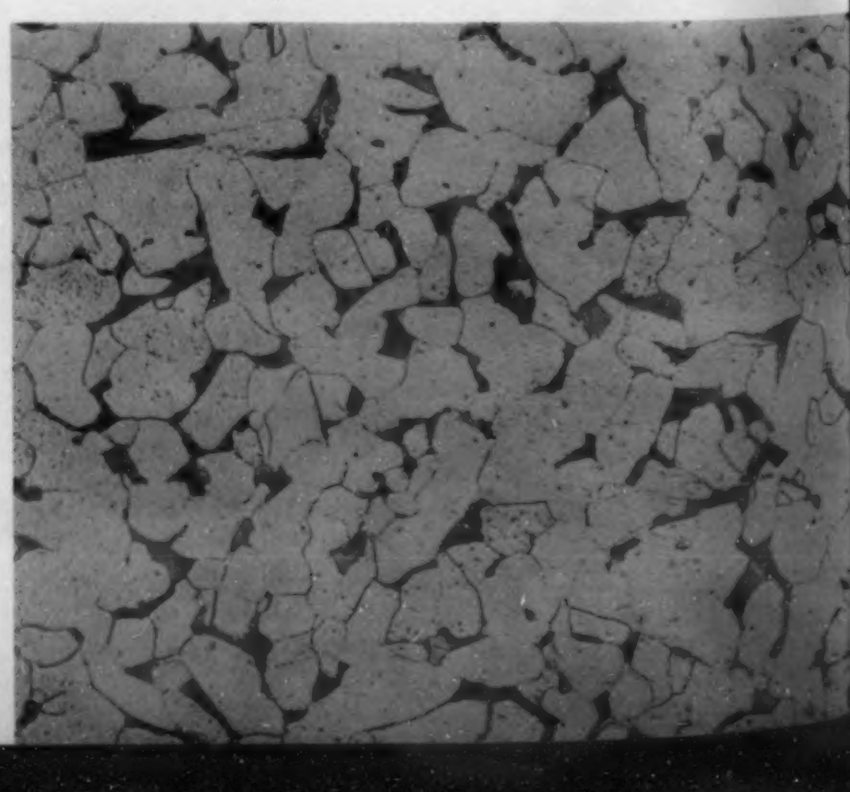


Fig. 4. *Structure at fracture of killed carbon steel. X250. Stresses at 8,000 lbs. per sq. in. for 1,875 hrs. at 1,000 deg. F. Elongation 27.5 per cent in 4 in. reduction of area 45 per cent.*

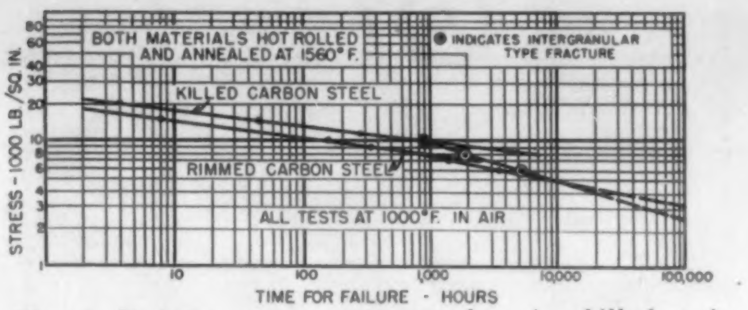


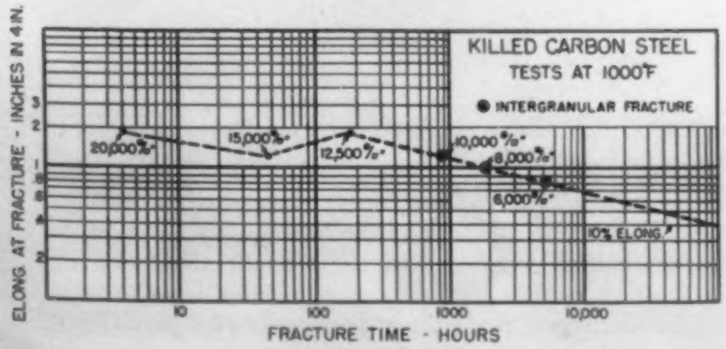
Fig. 3. Rupture curves at 1,000 deg. for killed and rimmed carbon steels.

Stress, Lbs. per sq. in.	Time for Frac., Hrs.	Elong. in 4 in., Per Cent	Red. in Area, Per Cent	Type of Fracture
	Killed Steel			
20,000	4	47.5	89	Transcrystalline
15,000	48	30	77.5	Transcrystalline
12,500	186	46	70	Transcrystalline
10,000	894	34	50	Intergranular
8,000	1875	27.5	45	Intergranular
6,000	5100	20	38	Intergranular
	Rimmed Steel			
20,000	35 min.	47	88.7	Transcrystalline
15,000	8 hrs.	31.2	80.8	Transcrystalline
10,000	169	53	90	Transcrystalline
9,000	337	59	88	Transcrystalline
7,000	1434	61	82	Transcrystalline
6,000	3570	59.5	67	Transcrystalline

The log-log rupture curves for these results are shown in Fig. 3. Typical microstructures of the long-time fractures are shown in Figs. 4 and 5 for each material. It is evident that although the rimmed steel is somewhat weaker in rupture and probably creep, the amount of hot ductility accompanying long-time fractures is considerably greater than is that of the killed steel. By extrapolation, the minimum elongation at fracture that could be expected in 100,000 hrs. for the killed material, as shown in Fig. 6 from the log-log plot would be about 10 per cent in a 4-in. gage length.

For the test of longest duration on the killed material creep measurements were obtained. The resulting creep curve, as shown in Fig. 7, indicates that the regions of decreasing and constant creep rates are exceeded before 1 per cent of plastic strain has occurred. Fig. 8 is a logarithmic plot of the results shown in Fig. 7, and indicates the phenomenon more clearly. These results suggest the possibility that carbon steels at 1000 deg. F. may actually be in a state of failure under conditions of

Fig. 6. Elongation at fracture—time curve for killed carbon steel.



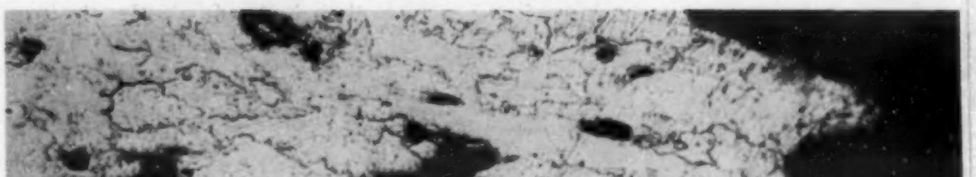


Fig. 5. Structure at fracture of rimmed carbon steel. X250. Stressed at 6,000 lbs. per sq. in. for 3,570 hrs. at 1,000 deg. F. Elongation 59.5 per cent in 4 in. reduction of area 67 per cent.

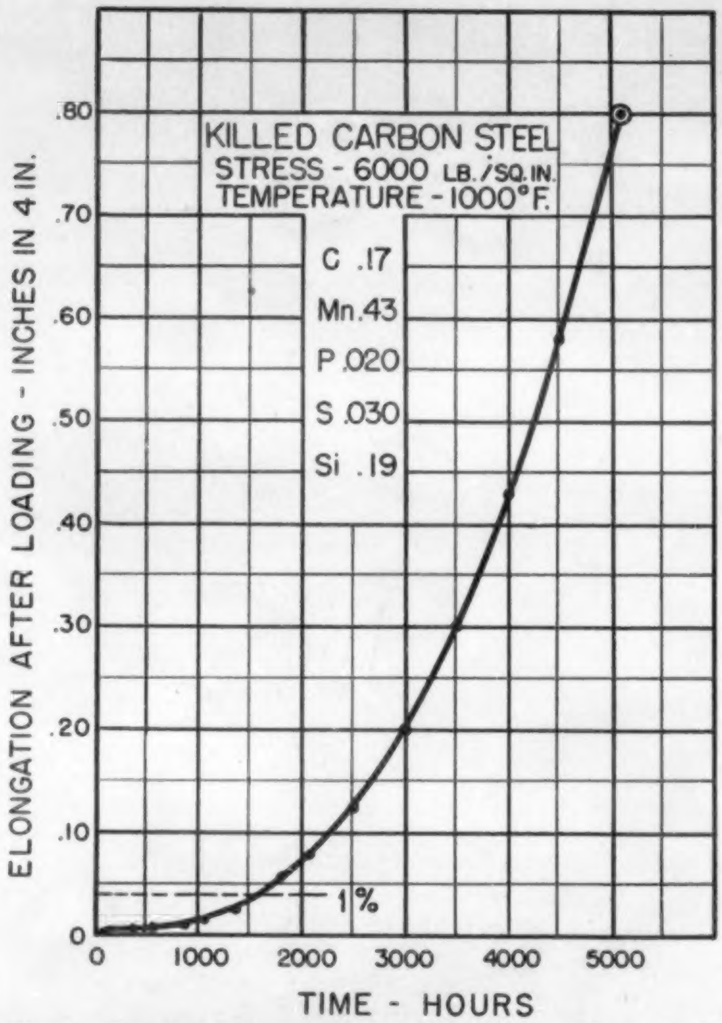


Fig. 7. Creep to fracture curve for killed carbon steel.

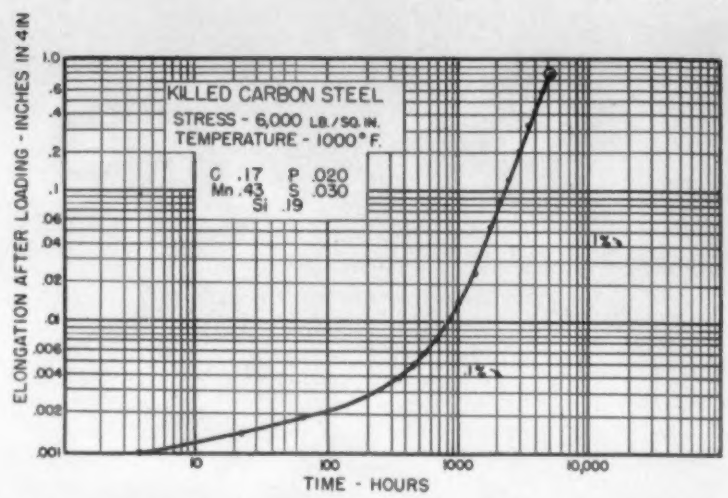


Fig. 8. Creep to fracture curve for killed carbon steel.

constant stress after very small values of plastic strain have occurred.

R. H. Thielemann

Research Laboratory
General Electric Co.
Schenectady, N. Y.

Editorial Comment

It is worthwhile to have on record such data as are here presented by Mr. Thielemann. However, laboratory results of this sort should not make the engineer close his eyes to the fact that long service of plain carbon and carbon-molybdenum steels, at loads and temperatures dictated by past experience, has been so devoid of failures of this type that publication of an instance of actual failure is in the nature of a museum exhibit.

That such steels, at loads and temperatures used in sensible design, serve out their allotted lives, even though if mistreated by excessive loads or temperatures, this type of failure can be produced, merely indicates that a good thing can be mistreated. We do not condemn blotting paper because it does not serve as armor plate.

In considering data of the type presented by Mr. Thielemann, let's be thankful for the data, but let's preserve our sense of perspective.

Who, in his senses, suggests using even killed carbon steel at 6,000 lbs. per sq. in. at 1,000 deg. F.? The Boiler Code limits loading to 5,600 lbs. per sq. in. at 900 deg. F. and to 2,000 lbs. per sq. in. at 1,000 deg. F.—H.W.G.

Continuous Casting—Hazelett's New Mill

To the Editor: Permit me to call your attention to a misstatement which appeared on page 68 of the July issue of Metals and Alloys.

In the last paragraph of the composite digest on "Continuous Casting" you state that "American Metal Co. and Scovill Mfg. Co. are jointly experimenting with Hazelett's new ring-type mill, which can turn out metal at 500 ft./min., produces brass comparable in ordinary physical properties with conventionally made materials, and is etc."

Please note that neither The American Metal Co. Ltd., nor the Scovill Manufacturing Co., nor these two companies jointly, have carried out any experiments with Mr. Hazelett's ring-type mill. All of the experimental work which these companies conducted some years ago was done with Mr. Hazelett's earlier type mill so modified as to permit careful control of the temperature and the atmosphere surrounding the metal being roll-cast.

As a result of these modifications, it became possible to produce continuously a roll-cast sheet of oxygen-free metal having physical properties similar to those of the same metal made by the conventional methods. But as said before, this had nothing to do with Mr. Hazelett's so-called high speed mill.

Sidney Rolle
Assistant Manager

The Scomet Engineering Co., New York

Editor's Note: Mr. Rolle is of course correct. The statement published in our digest represents an editorial error on our part in preparing the "composite" in question, due to a misunderstanding of the true situation. Neither Mr. Hazelett nor the authors whose articles were incorporated in that digest made the statement in question.—F.P.P.

A Pb-Sn-As Wiping Solder

To the Editor: I was much interested to read in the March, 1940, issue of METALS AND ALLOYS, the article "A Lead-Tin-Arsenic Wiping Solder" by Schumacher and Phipps, in which it is claimed that a new wiping solder has the following virtues:

1. An increased buttery or plastic character.
2. A reduced tendency for oxide formation.
3. A more refined grain structure.

It seems peculiar that out of the multitudes of skilled artisans who have used arsenic solder (whether they knew it or not) for generations, no one has previously recognized its advantages. It seemed of interest to compare, as to drossing, the arsenic solder with ordinary solder of equal purity and under identical conditions.

Experimental observations were made as follows: Some 38/62 solder was prepared from Chempur tin (purity 99.99%) and electrolytic lead (purity 99.99%). Two 300-gram samples of the alloy were placed side by side in a two-compartment type porcelain crucible and heated over a Bunsen burner in such manner that both portions of metal were exposed to exactly equivalent thermal conditions. To one portion was added sufficient arsenic to make a 0.10 per cent arsenic alloy, and a little rosin to reduce oxidation and accelerate wetting; to the second portion was added rosin, but no arsenic. When the arsenic had dissolved, the ingots were removed and washed well in turpentine to remove all rosin; the crucible was also thoroughly cleaned. The ingots were then replaced in the crucible, and heated as before (but without rosin) until melted; the molten metal was then carefully skimmed. The temperature was then raised to 400 deg. C., and held constant for 6 hrs., at which temperature both metals formed a rich, golden colored oxide. At intervals of 1 to 2 hrs. during this period, the oxide was carefully skimmed from the surface of each metal and the gold-colored scum allowed to reform. No difference could be observed in the colors of the respective oxides, the rate at which they formed or the apparent volumes produced.

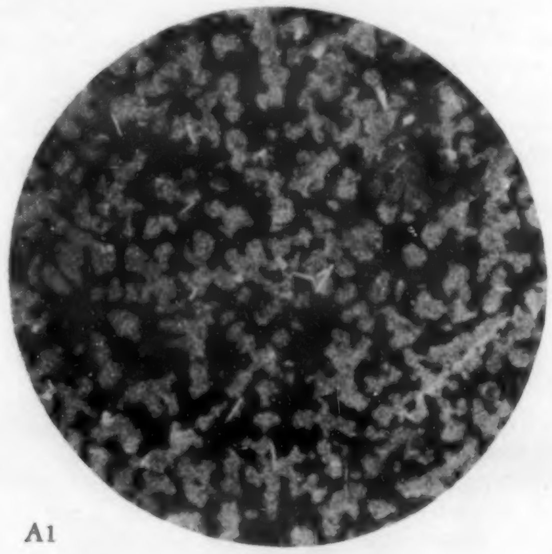
The tests were repeated at temperatures of 340 and 290 deg. C. The observations at these lower temperatures were the same as those at 400 deg. C., with the exception that the color of the oxide formed on the pure solder is slightly bluish while that on the arsenic solder remains more nearly golden. This slight difference in the color of the oxide does not appear to be associated with any difference in respective volumes and it hardly seems reasonable that ordinary solder will form more dross at a low temperature than at a high one. (Apparently no appreciable amount of arsenic was volatilized during these tests as the arsenic constituent can be readily identified in subsequent photomicrograph A1).

The observations of Schumacher and Phipps on microstructure require further interpretation and explanation.

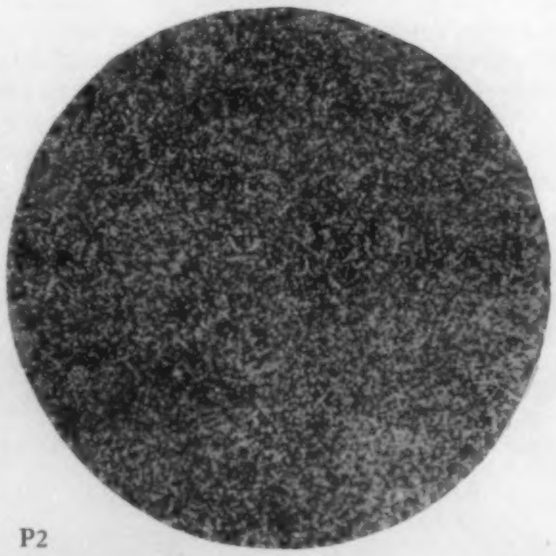
When molten solder is cooled slowly from a high temperature, the microstructure is dendritic whether the solder contains arsenic or not. Photomicrographs P1 and A1 reveal the microstructure of the pure and the arsenical solder at 50 magnifications when the two metals are slowly cooled side by side from a molten condition at 300 deg. C.

It is important to note, however, that solder is not applied this way commercially. The application of wiping solder in particular does not call for slow cooling from a

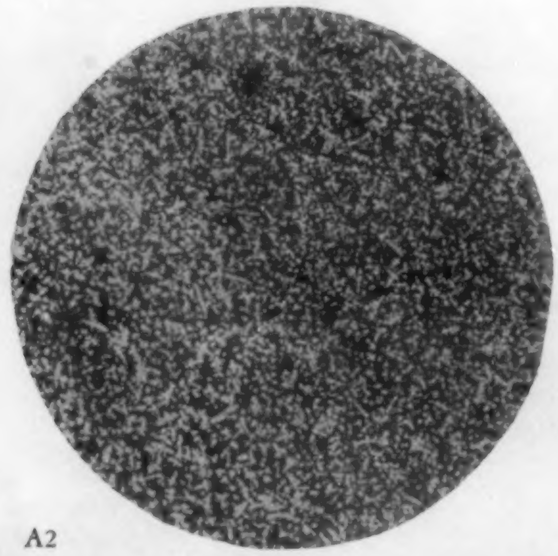
P1



A1



P2



A2

molten condition. Photomicrographs P2 and A2 reveal the microstructure of the two types of solder when cooled normally; it will be observed that there is no apparent difference in the microstructure of the two alloys. These conditions more closely approximate those encountered on a telephone wiping job.

These observations on microstructure should not be inter preted to mean that they are of particular practical significance. The quality of a soldered connection is determined by the extent to which alloy formation has taken place on the metal that is soldered; if thorough alloying action has taken place, it makes little difference whether the unalloyed solder is dendritic or not. Leakage in soldered connections is caused by inadequate alloy formation—not by porosity of component metals.

CLIFFORD L. BARBER,
Research Chemist,
Kester Solder Co., Chicago.

Roosevelt or Willkie?

To the Editor: One of my editorial associates has suggested that I send the editors of a number of business papers copies of an editorial published in the June 13 issue of *Railway Age*, and I am accordingly sending you a copy of it herewith.

I have devoted most of my active life to studying and writing on economic subjects, just as other men have devoted themselves to studying and writing upon engineering, legal or medical matters. There can be, and is, in my opinion, no disagreement among sane Americans regarding the imperative necessity of arming this country adequately to defend itself against any possible foes or combination of foes. I have no doubt that this policy will be followed whichever party is successful next fall.

This being the case, I believe that the real issues of this political campaign are (1) which candidate, if elected, is more likely to do an efficient job of providing for national defense, and (2) which is more likely to follow policies tending to revive business and thereby make the country better able economically to stand the strain and expense of military preparation.

On the record, I have no doubt whatever that, in view of the conditions confronting us and the problems which must be solved, Mr. Willkie would, as president, meet the test of these two issues much better than Mr. Roosevelt. I am as certain as I ever was of any future thing that, if Mr. Roosevelt is re-elected, there will not be for another 4 yrs. anything resembling real economic recovery and prosperity; while, if Mr. Willkie is elected, real economic recovery will begin the next day and continue until business in this country becomes as good as it ever was.

In view of these facts, the Simmons-Boardman publications, as *business* papers, will during this political campaign advocate the economic policies for which we believe Mr. Willkie stands, and oppose the economic policies for which we know Mr. Roosevelt stands and which have prevented recovery in this country for 7 yrs.

I would appreciate equally frank statements from you and other editors indicating what your policy during the political campaign is going to be.

SAMUEL O. DUNN

METALS AND ALLOYS is not a business paper; it's a journal of metallurgical engineering. It doesn't seem necessary to devote much space to so obvious a matter, for engineers can add up two and two to make four. In fact, we have met only one metallurgical engineer who was ever a New Dealer. This one was for a time, but when the Supreme Court packing attempt was made, he became, and remains strongly, anti-N.D. The Editorial Director of METALS AND ALLOYS agrees completely with Mr. Dunn.—H.W.G.

More on "Wanted-Words"

To the Editor: I was very much interested by the June editorial on yield strength.

With your entrance into the discussion I hope that a realistic mode of thought may come to prevail, and that a clear differentiation may be made between Yield Point, which is a definite characteristic of material, and the so-called Yield Strength, which exists only by some arbitrary definition.

Your suggestions are constructive, as always, but may perhaps be extended. I should like to offer some suggestions as to naming the babies you present. To clear the way I set down some of their genealogy, with which you are, of course, familiar. In 1927 Templin (*Proc.* A.S.T.M., Vol. 27, p. 244) and in 1928 Lessells (*Proc.* A.S.T.M., Vol. 28, p. 390) were talking about "Yield Point" (*sic*) determined by the plastic strain method. J. A. Capp protested (p. 393, Vol. 28) and at some later date the terminology was improved slightly, the plastic strain method point being named "Yield Strength," while the method was called the "offset method," a line being drawn parallel to the Young's Modulus line at an arbitrary offset, which for acceptance tests often corresponds to 0.2 per cent strain. The sponsors of this arbitrary characteristic of the material selected the name Yield Strength, probably because it was intended to serve some of the purposes of the well-established Yield Point value. This may have been helpful to the structural engineer, but unfortunately it suggests that the testing engineer has failed to recognize the essential difference between two different characteristics. Yield Point is a perfectly definite characteristic of wrought iron and the mild steels, while Yield Strength is determined by some arbitrary definition only. It seems regrettable that the old established name should have been so nearly infringed on.

If we are to work freely with routine acceptance by specifications requiring the offset method, and are also to study the habits of your "diaper yield strength," would it not be desirable to set up distinctive names to avoid confusion with the Yield Point?

We are dealing with a strength, perhaps more accurately a stress, at which there is a definite offset from the elastic line. I suggest as a generic name "Offset Strength." If this is accepted, your first indication of plasticity might well be named the "Nascent, or 2/100 per cent Offset Strength." This might be abbreviated to the "N Offset Strength." The acceptance specification limit, or the value to be used by the structural designer, represents a point at which plasticity begins to be fully developed, the dangerous stage appears; and for this I suggest the "Pubescent, or 2/10 per cent Offset Strength," easily nicknamed the "P Offset Strength."

If "Offset Strength" were adopted, the Navy Proof Stress could logically be named "Strain Strength," with a determining percentage as a prefix.

Also, with the N and P Offset Strengths understood, it would be convenient to talk of the N/P Ratio and study this for the various materials.

If you think well of these names, I see no reason why the A.S.T.M. should hesitate to accept definitely descriptive names. It seems to me that Yield Strength would be better off if it had a name of its own and did not use one which suggests that it is trading on the reputation of its older brother, Yield Point.

LAWFORD H. FRY
Edgewater Steel Co., Pittsburgh, Pa.

P.S. Since this was written I have seen Prof. H. F. Moore's letter on the subject in your July issue. His suggestion of "Offset Yield Strength", abbreviated to "oys" is good, but I think that it can be simplified and improved by going to "Offset Strength" with the abbreviation "o. s." analogous to T. S. for Tensile Strength. L.H.F.

METALLURGICAL ENGINEERING news

Equipment
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Alloys
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People
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Societies

WELDING AND CUTTING

It would seem as though the story of the advantages in and the expansion of welding as a fabrication method has been told so often that further comment is superfluous, yet it is true that new applications are constantly being made, and in many of them new design twists or previously-undiscovered welding-values are involved. One factor that has been both a cause and an effect of welding expansion is the continual development of welding equipment, materials, electrodes, rods, etc. offering the metallurgical engineer new processing economies or better quality welds and welded products.

The foundryman's early and understandable antipathy to welding has been gradually overcome through his recognition of its utility in the production of composite (welded castings) fabrications, and through its value in repairing defective or broken castings. General Electric Co., Schenectady, N. Y., for example, recently reported that the repair of a break in the bed of a 50-ton cast iron stamping press by arc welding saved its owners (the Samuel Stamping and Enameling Co., Chattanooga, Tenn.) more than $1000 in replacement cost and several days of production time. Using GE shielded arc electrodes, the break (through a section 30 in. long, 12 in. deep and 4 in. thick) was welded without preheating or machining at a cost of only $125. The record is full of similar cases.

The great dependence of engineers on modern welding as a fabrication method is well illustrated by a report, also from General Electric, that on the recent foundation construction of three Cleveland bridges two 300-amp. GE arc welders were kept going continuously for 3 months, 3 shifts a day, without even a shut down between shifts.

An Arc Welder for Light Work

With all the development of better welding equipment in recent years, the production of satisfactory arc welds in metals thinner than 18-gage has remained a problem. Originally for their own requirements of this type and now for general sale, Allis-Chalmers engineers developed the "Weld-O-Tron", a new low-current electronic welder that can weld sheets as thin as 32-gage.

Hardware, cutlery, small alloy castings, light seamless tubing, business machine assemblies, auto bodies, trains and airplanes are all mentioned as fields for application of this new welder. With it currents as low as 5 amps. can be used, employing specially developed 1/32 and 3/64 in. electrodes for better control in fast, accurate welding.

The Weld-O-Tron electronic arc welder is a portable 6-tube mercury arc rectifier that converts a.c. into d.c. for welding purposes, using the newest type of hot-cathode rectifying tubes. The claimed superiority of the joints it produces over the soldered or brazed joints commonly used for thin metals are said to open innumerable design possibilities for the engineer.

New Diesel Arc Welder with Gas-Engine Starting

The application of gasoline engine starting on diesel-driven arc welders, announced previously on a 300-amp. unit by Lincoln Electric Co., Cleveland, Ohio, has been further extended to a 400-amp. model. This advance is said to make available easy starting in any weather plus the inherent economies of diesel drive in the many applications for engine-driven welders of capacities up to 400 amps.

The gasoline engine is a small auxiliary mounted above the diesel, and is started by means of a hand crank. The "Shield Arc SAE" arc welding generator on the new diesel welder is equipped with "dual continuous control" of arc voltage and current and other Lincoln features. The price of the new equipment is said to compare favorably with conventional gasoline-engine-driven arc welding sets.

New Build-Up Welding Rod

Intelligent use of available electrode materials and types is half the battle in obtaining good welds, whether for production or repair. The American Manganese Steel Div. of American Brake Shoe & Foundry Co., 389 E. 14th St., Chicago Heights, Ill., has introduced Amsco Mo-Mang welding rod, described as a low-cost manganese-molybdenum steel rod for building-up worn high-manganese, carbon steel and gray iron castings.

Available in 18-in. lengths in the bare form for straight d.c. welding and in the combination coated form for both d.c. and a.c. applications, Amsco Mo-Mang is recommended for straight build-up welding to compensate for wear as encountered by bucket lips, crusher hammers, jaws, etc. It is not intended to replace Amsco Nickel Manganese rod for high tensile strength and shock resistant service.

Auxiliaries for Arc Welders

Two manufacturers have just announced additions to their lines of arc welding auxiliaries. To permit the use of arc welding machines—such as the Wilson "Hornet"—on either of two line voltages at different times, a new dual voltage switch (type CH) has been developed by Wilson Welder & Metals Co., Inc., 60 E. 42nd St., New York. The new device can be used on any a.c. motor provided the motor and starter are reconnectable for 2 voltages.

With the switch installed, the change from one line voltage to another requires less than a minute, as compared with the usual ½ to 2 hrs. for changing heater elements, and disconnecting and reconnecting the motor and magnet coil leads. The standard dual voltage switch is designed for 220-440 volts of a delta-connected motor, but other connections are readily obtainable.

A new paralleling arrangement to combine the capacities of two or more P&H Hansen WD-150 welders has been developed by Harnischfeger Corp. of Milwaukee. With the new hook-up, an operator has at his disposal the aggregate cur-

rent of two or more machines for peak loads. When the connection is cut, each machine can be used separately, thus doubling or tripling welding production, it is said.

The square frame design of these welders enables them to be stacked one above the other for multiple operation. Current selection is accomplished by a single control, the generator automatically responding with the desired current.

New Spot Welder

A new improved line of foot-operated rocker arm type spot welders with all-welded steel bases and other innovations is announced by Acme Electric Welder Co., Huntington Park, Cal. Type O, with stationary lower horn holder and Type 1 with swivel lower horn holder are manufactured in 10, 15 and 20 kva. capacities and in throat lengths of 12 to 36 in., complete with water-cooling equipment.

These Acme "Hot Spot" welders, as they are known, feature the use of malleable iron or steel for major mechanical parts, pure electrolytic copper castings for extra heavy horn holders, cadmium plating on exposed steel parts, bronze bushed steel rocker arm bearings and high grade silicon-coated transformer iron.

Bronze Welding

A new liquid flux and its dispenser, for use in bronze welding ferrous and non-ferrous materials, have been announced by Linde Air Products Co., a unit of Union Carbide and Carbon Corp., 30 E. 42nd St., New York. Called "Oxweld Brazo Vapor Flux", the new agent is said to be of greatest value on production work where the bronze-welding operation is continuous, the metal sections being joined are relatively light, and the joint is sufficiently exposed.

Because of the economical method of application, the flux is active only at the actual point of contact of the flame, and its use is therefore limited to standard bronze-welding applications that do not depend on capillary flux action. It is not generally recommended for use on cast iron, although satisfactory results can be obtained if the cast iron is clean.

The new flux must be used in conjunction with a special dispenser of the bubble type. Application of the flux is automatically controlled, with no waste from excessive use of flux, it is said. One gallon of the new material is sufficient to flux 1000-1500 cu. ft. of acetylene.

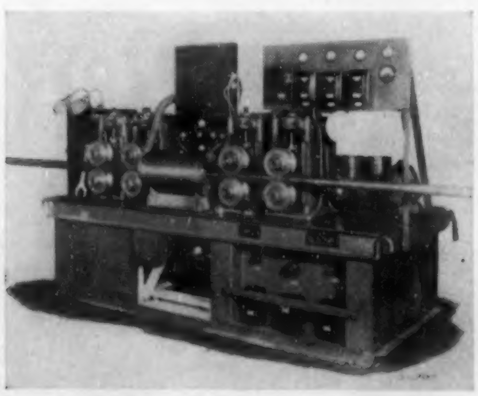
Flame Positioner

A recent addition to the line of welding stands manufactured by Cullen-Friestedt Co., Chicago, Ill. is the new 1200-lb. capacity Model 12 positioner. Like other positioners of this line, the new model can be tilted a total of 135° from horizontal and the table can be revolved through a full circle regardless of angle of tilt. The table is removable for jig or fixture attachment and is adjustable in height.

The new unit can be furnished for manual operation, or fully-powered with independent motor and controls for table tilt and rotation. It is claimed that the universal table adjustment reduces the number of passes required, diminishes rod consumption and improves weld quality by permitting all work to be done in a horizontal trough.

Electric Tubing Inspector

With tubing coming into constantly wider use, not only for carrying liquids or gases but for structural purposes as well, considerable interest is attached to equipment for rapid detection of defects in tubes. Sperry Products, Inc., Hoboken, N. J., has developed a non-destructive electric "detector" for production inspection in tube mills that is claimed to be able to detect slivers, seams, dents, leakers in welds, etc. at speeds of 30 to 100 ft. per min., in non-magnetic or magnetic metals.



The defects revealed may be internal or external, visible or invisible to the eye, and upwards of 1/8 in. long with depth equal to 1/2 the wall thickness. The detector is said to be compactly constructed and to be amenable to simple and efficient operation by one man; automatic control stops the tube movement at each defect signal. The detector is supplied on a rental basis.

Rearmament and Carbide Tools

At the risk of being repetitive—which under the circumstances is hardly a damning indictment—we emphasize once more the important facts that time is of the essence in the National defense program, that heavily "tooled" industries like the automotive cannot from dusk to dawn be converted to "1,000-a-day" aircraft production, and that every feasible means of increasing machine tool capacity must be employed if serious delays are not to be suffered.

A. C. Wickman, president of A. C. Wickman, Ltd., a leading British machinery manufacturer, and also president of the British Hard Metal Association, stated recently that automotive equipment has proven useless for the production of aircraft and aircraft engines in England. Strictly automobile manufacturing equipment can be used in war time only for the production of ambulances, trucks and similar vehicles. British rearming, long delayed, is now vitally dependent on maximum production from relatively new factories with entirely new equipment solely for the manufacture of aircraft.

Every device possible to squeeze the maximum production from all British armament plants is now employed, and particularly the use of carbide cutting tools for stepping up production, not only of armament itself but of the machinery for its manufacture. With the use of these carbide materials, Wickman said, production has been multiplied 4 times for steel and 6 times for cast iron. For example, certain operations in the machining of 3.7-in. shells that required 28 min. machining time in the last war are now completed consistently in less than 5 min. Wickman added that American application of carbide tools is way behind British and German.

However, several American machine-tool manufacturers are already reported by Carboloy Co., Inc., Detroit, to have increased their effective production capacity 30 to 50 per cent through the use of cemented carbide tools for machining steel as well as cast iron. Impressive improvement figures are cited for Gisholt in turning SAE 1045 steel spindle shafts; for Monarch (nearly 300 per cent increase) in machining SAE 2350 lower gear shaft boxes; for Warner and Swasey on rough and finish machining hand-forged spindles; for Bullard on SAE 1045 spindles; for Gisholt on taper boring Ampco No. 18 bronze worm wheels, and many others.

Motorized Nose-Pour Crucible Melting Furnace

Brass, aluminum, nickel, iron and rare metals are among the materials that can be efficiently melted in a new motorized nose-pouring crucible furnace, according to its manufacturers, Fisher Furnace Co., 1740 North Kolmar Ave., Chicago. The furnace is said to be particularly well adapted for

ingots, permanent mold castings, filling transfer ladles, pouring bearing metals, etc.

The pouring operation is completely motorized, with positive-safety, finger-tip control. The special trunnion mounting permits low construction and is so located with respect to the pouring lip that a constant pouring arc is maintained regardless of degree of tilt. The rate of pouring is under instant and positive mechanical control, and automatic "safety stops" prevent the operator from tilting the furnace beyond the two maximum extremes of the tilting range.

The furnace, available in either oil or gas-fired units, is built in sizes for crucibles 150 to 400.

Continuous (Impact) Casting

Details of the Merle process for "impact casting" of such products as ingots, slabs, tools, sand castings, die castings and direct-rolled strip have been sent to us by J. M. Merle, 9641 So. Oakley Ave., Chicago. The process was mentioned in a composite digest on "Continuous Casting" in our July issue (p. 66) but no adequate description was given there or in the original articles from which the "composite" was prepared.

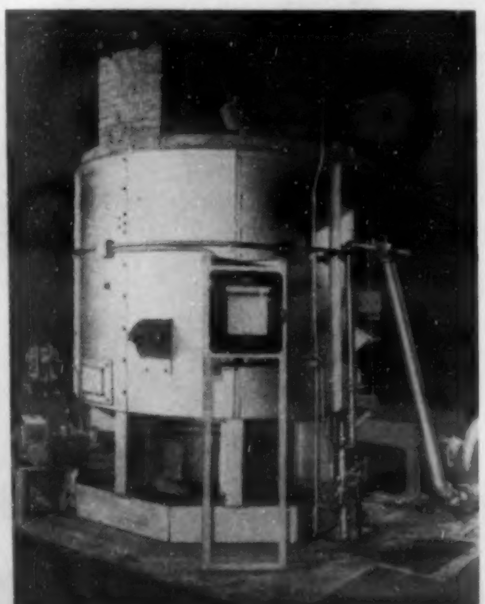
In the Merle "film impact" method, the molten metal stream from the ladle is continuously and instantaneously formed into a thin film of controlled thickness propelled at high velocity by a moving, clean metallic section selected as to nature and dimensions to produce the maximum heat-removal from the molten metal film. The length and periphery are designed to permit continuous transfer of the heat received to the air or to a liquid coolant.

It is stated that crystallization is uniform, gases are eliminated and segregation absent. The super-cooled film is directed into the mold to strike it under high velocity, or through lower-velocity feeding nozzles for sand castings, if desired. For direct rolling of thin strip of all metals, including bimetallic strip, the molten metal film is formed to the desired dimensions through control of the peripheral velocity of the forming rim. The top roll is water-cooled and counter-balanced.

Center-Fired Rotary Furnace

A new type of rotary forging and heat treating furnace developed by Mahr Mfg. Co., Minneapolis, Minn., is said to offer unusual temperature uniformity within the furnace, together with a minimum of scaling and decarburization, by virtue of its single-burner center-firing design.

A single burner at the bottom of the hearth fires up through a long combustion cone, which gives the combustion-product system full opportunity to attain equilibrium before coming in contact with the steel. This principle is also claimed to provide a furnace free from cold spots, even at the furnace door. The single burner feature is said to assure close uniform control over furnace atmosphere, too.



The furnaces are either oil- or gas-fired, provide temperatures from 1400 to 2500 deg. F., and are available in hearth diameters from 4 to 9 ft. Other interesting features are an automatic stack damper for maintaining positive pressure within the furnace, a new improved type of sand seal, and a special air-curtained door to protect the operator from the heat.

● Breakage of the porcelain on spark plugs by steel sockets on the spark plug wrenches has been eliminated by tool manufacturers who have redesigned the tool by modifying its shape and dimensions and by using neoprene inserts inside the steel socket, reports the Rubber Chemicals Div. of E. I. duPont de Nemours & Co., Wilmington, Del.

Pot-Hardening or Non-Ferrous Melting Furnace

Of interest to tool and die shops and to others concerned with salt, cyanide and lead hardening, and also to pattern and model makers or others required to melt small amounts of aluminum, brass, etc., a new melting and pot-hardening furnace, No. 550, is announced by Johnson Gas Appliance Co., Cedar Rapids, Iowa. The model is especially convenient for small parts or for small-volume production.

The equipment as illustrated, complete with lid derrick for lifting lid, Johnson blower and steel pot (8 in. diam. x 10 in. deep) is priced at $112.00 f.o.b. Cedar Rapids. Temperature is said to be easily regulated and gas consumption is reported to be low.

● The formation of the Fred J. Ryan Co., 5244 Germantown Ave., Philadelphia, for rendering general furnace and industrial metallurgical service in the Eastern area is announced by Fred J. Ryan, previous president of R-S Products Corp., who disposed of his interest in the latter corporation over a year ago.

● To isolate sections of the new Boston pressure aqueduct temporarily when tests are made for water-tightness, dished bulkheads formed to shape from one piece of rolled steel plate will be used. The bulkheads, over 11 ft. in outside diameter and 1 in. thick, were manufactured by Lukens Steel Co., Coatesville, Pa.

Gray Iron Research Program

The recently-organized Gray Iron Research Institute has arranged to conduct a program of foundry research at Battelle Memorial Institute, Columbus, Ohio, the director of the latter institute announces.

The Gray Iron Research Institute, chartered as a non-profit corporation to engage in research for the "gray iron industry", includes among its charter members Advance Foundry Co., Buffalo Foundry and Machine Co., The Bullard Co., Carondelet Foundry Co., Chicago Hardware Foundry Co., Forest City Foundries Co., Fremont Foundry Co., Spring City Foundry, United States Pipe and Foundry Co., and Worthington Pump and Machinery Co.

The first part of the program, investigation of the fundamental principles of cupola melting, is expected to provide the groundwork for more accurate control of metal quality and lower operating costs for the member foundries. At Battelle the experimental work will be directed by Dr. C. H. Lorig and Mr. R. A. Sherman. Mr. John Lowe will serve as contact man between the laboratories and the member foundries.

● Ninety per cent of a group of housewives who had been using refrigerators with porcelain enamel finishes over 5 years answered *yes* to the question, "Do you want the same finish on your next refrigerator?" when it was asked in a recent survey by Porcelain Enamel Institute, 612 North Michigan Ave., Chicago, the Institute reports.

Lightweight Compressor

Ingersoll-Rand Co., Phillipsburg, N. J., has just introduced a new 2-stage air-cooled compressor, known as the D-60, that delivers 60 cu. ft. of free air per min. at a discharge pressure of 100 lbs.

The unit is reported to be inexpensive, reliable, compact and light in weight. It will operate most of the grinders, paint-sprays and other pneumatic tools that are in common use with much larger portables. Three types of mountings are available, all built around the same gasoline engine-compressor plant—the *Pushabout* (illustrated); the *Deluxe*, a spring-mounted, high-speed trailer unit with built-in tool boxes; and the *Utility*, mounted on a steel base and capable of direct mounting on a service truck.

New Appointments and Promotions for Metallurgical Engineers

H. M. Lane, with 40 yrs. experience in the design of foundries and the installation of equipment, has become foundry research engineer for Paul Maehler Co., Chicago. . . .*C. S. Thayer,* superintendent of the Niagara Falls plant of Aluminum Co. of America, has been made general plant superintendent of the company's new Vancouver, Wash., plant. . . . *William F. Zerbe,* chief metallurgist of Central Iron and Steel Co., Harrisburg, Pa., has become assistant general superintendent, succeeding *A. E. Eck,* elevated to general superintendent of operations of that company. . . .

Elmer E. Legge, formerly district director of research at Worcester for American Steel and Wire Co., has been appointed assistant director of research for the company at its Cleveland offices. . . . *Derick S. Hartshorne, Jr.* is the new technical director of Enthone Co., manufacturer of plating and finishing chemicals, New Haven, Conn. . . . *John Lowe* recently joined the technical staff of Battelle Memorial Institute, Columbus, O. as foundry engineer. . . . *Leon B. Rousseau,* formerly industrial heating specialist for General Electric Co., has been named district sales manager for Ajax Electric Co., Inc., Philadelphia. . . .

J. C. Witherspoon of American Steel & Wire Co. is being transferred to general superintendent of the steel division at Duluth from assistant general superintendent at Donora Steel & Iron Works. . . . His place at Donora will be taken by *Harold Cope,* until now superintendent of blast furnaces there. . . . *Herman J. Hofmann,* assistant open hearth superintendent of Lukens Steel Co., Coatesville, Pa., has been promoted to open hearth superintendent. . . . *Floyd Stroup* is now superintendent of the melt department of Copperweld Steel Co.'s new plant at Warren, Ohio.

Contacts for High Current Switch

A new 3-pole outdoor disconnect switch, designed for a 4,000-amp. load at 23,000 volts, posed a real contact-material problem for its manufacturer, the Pringle Electrical Mfg. Co., Philadelphia.

Because of the high amperage, it was necessary to employ a contact material that combined high conductivity with low, constant contact drop to assure continuous minimum operating temperature. Finally chosen were Gibsoloy grade A-8 contacts (60 per cent silver and 40 per cent nickel), manufactured by powder metallurgy processes by the Gibson Electric Co., 8356 Frankstown Ave., Pittsburgh. These contacts are said to fulfill these primary requirements to a high degree, and in addition to provide other operating advantages.

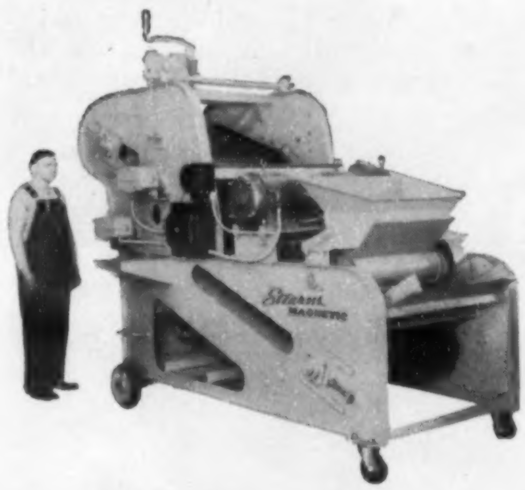
"Nor Iron Bars a Cage"

Metallurgical engineers, we've often declared, are found practically everywhere. From McKenna Metals Co., Latrobe, Pa., we learn that they're even in jail, for an inmate of a large eastern prison recently requested a copy of a bulletin about Kennametal, a hard carbide tool material. Since Kennametal is considered to be particularly useful for cutting hardened steel such as is used in prison bars, the prisoner's motives were immediately suspect, although it was finally learned he was interested merely in improving the efficiency of the prison machine shop.

What a dismal shock this must be to those thousands of metallurgical engineers who looked with starry-eyed hope on our penal institutions as a possible final refuge from this world of specifications, cost sheets and delivery promises.

New Magnetic Separator

Metallurgical engineers in smelter plants and other shops that must continually separate brass and iron or steel turnings and borings will be interested in a new double



magnetic pulley separator unit developed by Stearns Magnetic Co., Milwaukee.

In operation, the material to be separated may be fed either into the bulk hopper with louvre-feed or into a chute below. The coarse material is picked up by the upper pulley, with the lower serving as a refining operation. Long and odd-shaped pieces are fed into the lower chute.

A winch is provided for raising or lowering the upper magnetic pulley to accommodate various sizes of material being separated. The separator can be furnished in a wide variety of sizes and combinations. Magnetic pulleys ordinarily operate off d.c. current and can be wound to correspond to any desired voltage.

Loading Shell Forging Furnaces

Recognizing the need for limiting both the temperature and the loading of shell forging furnaces (without limiting furnace design initiative) the Ordnance department, upon the recommendation of the Industrial Furnace Manufacturers Assoc., has adopted Amendment No. 2 of July 2, 1940, to shell forging specification No. 57-104-24.

The amendment recommends that the operating temperature of forging furnaces be restricted to a maximum of 2300 deg. F. to avoid overheating the surface of billets to the point where the steel drips or flows. Loading of forging furnaces should be kept under 60 lbs. of steel heated per hr. per sq. ft. of hearth area available for loading. Each billet should be exposed in the furnace for individual heating to avoid non-uniformity in each billet and to assure billet-to-billet uniformity for subsequent press operations.

Meetings and Expositions

AMERICAN CERAMIC SOCIETY, Porcelain Enamel Institute Forum. Urbana, Ill., Oct. 16-18.

AMERICAN GAS ASSOCIATION. Atlantic City, N. J., Oct. 7-10.

AMERICAN GEAR MANUFACTURERS' ASSOCIATION, semi-annual meeting. Skytop, Pa., Oct. 14-16.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, fall meeting. Cleveland, Oct. 21-23.

AMERICAN MINING CONGRESS, annual western convention and exposition. Colorado Springs, Colo., Sept. 16-19.

AMERICAN SOCIETY FOR METALS, annual meeting. Cleveland, Oct. 21-25.

AMERICAN SOCIETY OF TOOL ENGINEERS, semi-annual meeting. Cincinnati, Ohio, Oct. 17-19.

AMERICAN WELDING SOCIETY, annual meeting. Cleveland, Oct. 20-25.

ASSOCIATION OF IRON & STEEL ENGINEERS, annual meeting and exposition. Chicago, Sept. 24-27.

ELECTROCHEMICAL SOCIETY, fall meeting. Ottawa, Canada, Oct. 2-5.

NATIONAL METAL CONGRESS AND EXPOSITION. Cleveland, Oct. 21-25.

SOCIETY OF AUTOMOTIVE ENGINEERS, national aircraft production meeting. Los Angeles, Calif., Oct. 31, Nov. 1-2.

SOCIETY OF AUTOMOTIVE ENGINEERS, national tractor meeting. Milwaukee, Wis., Sept. 24-25.

WIRE ASSOCIATION, annual meeting. Cleveland, Oct. 21-24.

Aluminum Alloy Castings

National Bronze and Aluminum Foundry Co., East 88th & Laisy Ave., Cleveland, announces the availability of T-1 aluminum alloy for sand and permanent mold castings. Castings of this alloy are said to have tensile strengths up to 33,000 lbs. per sq. in. and 6-10 per cent elongation, without heat treatment.

This alloy, which is described as meeting all requirements as given in Air Corps Specifications Nos. 11324 and 11325 and Navy Aeronautical Specification No. M-397 for aluminum alloy and sand castings, is claimed to produce superior castings without warpage or severe internal stress and with excellent machinability and corrosion resistance. T-1 alloy is available in ingots or as castings manufactured to customers' specifications.

Free Service Department

Replies to box numbers should be addressed care of METALS AND ALLOYS, *330 W. 42nd St., New York.*

WANTED: Man technically trained with practical experience in metallurgy or chemistry, for work on commercial development of inventions. In replying give personal data and details of education and experience. State minimum salary acceptable. Box MA-22.

POSITION WANTED: Junior Metallurgical engineer, 23, single. Graduate of University of Alabama, B.S. metallurgical engineering. Excellent references. Will go anywhere. Box MA-23.

Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

1. Production

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die-Castings.

2. Processing and Fabrication

Drop and Hammer Forging, Drawing, Extruding, Stamping and Machining. Age-Hardening, Annealing, Carburizing, Hardening, Malleableizing, Nitriding, Surface-Hardening and Tempering. Heating Furnaces, Refractories, Fuels and Auxiliaries. Welding, Flame-Cutting, Hard-facing, Brazing, Soldering and Riveting. Cleaning, Pickling, Electroplating, Galvanizing, Metallizing, Coloring and Non-Metallic Finishing.

3. Properties and Applications

Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

4. Testing and Control

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings. Surface Measurements. Metallographic Structure and Constitution.

5. General

Articles pertinent to more than one of the previous sections.

1 Production

OF METALS, MILL PRODUCTS, CASTINGS

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die Castings.

Vacuum Melting Furnace

"Controlled Melting, Pouring." *Steel,* Vol. 106, June 3, 1940, pp. 64, 82. Descriptive.

A new vacuum induction melting and pouring furnace having 50 lbs. capacity for the preparation and study of pure metals has been developed. It consists of a manganese steel cylinder about 30 in. in diam. and 35 in. long, in which the induction coil is set centrally, with about 10.5 in. between the outside surface of the coil and the case. Manganese steel is non-magnetic, hence the electromagnetic energy loss is low.

The ingot mold is clamped with small wedges in a steel cylinder projecting at a downward angle of about 70° from the side of the main cylinder and about 1/3 of the way from the furnace top. A plate is bolted to a flange on the bottom of the mold container. Only a few small bolts are required as the vacuum holds the furnace lid and mold plate firmly against the rubber gaskets.

The vacuum is held to 1½ mm. of mercury by a 26 ft.^{3} pump. The most difficult period for keeping the pressure down is just as the metal melts. Much of the difference in pressure is thought to result from the evolution of gases from the refractory linings.

A 50-lb. charge can be melted and poured in 15 min. from a cold start, using power supplied by a 100-kw., 2,000-cycle generator. At atmospheric pressure, the same charge can be melted and poured in about 11 min. Heats can be held to permit slag and oxides to rise to the surface.

MS (1)

Steel and Non-Ferrous Castings—A Review of A. F. A. Papers

"Improving Steel and Non-Ferrous Castings." *Can. Metals Met. Inds.,* Vol. 3, June 1940, pp. 147-151. A review of papers presented before the 1940 convention of the A. F. A. at Chicago.

The application of controlled directional solidification to the production of large and intricately shaped castings was described by J. A. Duma & S. W. Brinson. [For details of this technique, see Metals and Alloys, Vol. 11, May 1940, p. MA 252.] In an investigation of the weldability of cast steel, A. J. Smith & J. W. Bolton (Lunkenheimer Co.) show that structures developed in steels of 0.25% C equalled those in steels containing 0.15% C, with "granulation" of the latter definitely inferior. With good welding practice, sound high strength welds were made with all cast steels investigated, even with a 0.35% C content. Dangers of indiscriminate preheating before welding are described.

Steel—Chills and Chaplets

The application of external chills in the production of steel castings was discussed by W. F. McKee (Key Co.), particularly for the dissipation of excess heat. External chills have the advantage that exact size is not so important, but a disadvantage is that they nearly always require casting, machining, or burning to fit the section they are to fit.

Howard F. Taylor & Edward A. Rominiski (Naval Research Lab.) showed the influence of chaplets on the soundness and quality of steel castings. Factors affecting chaplet reactions are: Diameter of chaplet supporting rod; design of chaplet, especially the supporting rod; temperature of the cast metal surrounding the chaplet; material of the chaplet; composition and quality of plated, dipped or alloyed exterior chaplet covering; cleanliness of surface both before and after coating; and mold conditions.

Threaded stem chaplets do not present added assurance of satisfactory fusion and may be deleterious by providing spaces at the bottom of threads for the accumulation and localization of dust, moisture and subsequent gases. The threaded stem types do promote a keying action by fusion at the points of the threads. The square stem type twisted torsionally might give this desired keying action, and at the same time, would be stronger and obviate the existence of sharp V's. Too heavily alloyed chaplet material fuses readily, but may melt too easily for suitable core support. A properly chosen, thinly-impregnated case would promote the necessary fusion, and yet the base material would probably not melt too readily.

A good grade of low-carbon steel is well chosen for chaplet material in steel castings. Silicon-impregnated chaplets fuse readily. A certain amount of grain-coarsening results in the casting for a small distance around the imbedded chaplet. Copper- and nickel-plated chaplets prove satisfactory when properly prepared and kept clean. Silver-plated chaplets were best. So-called "streamlining" of chaplets would obviate the tendency of gases to form and localize in indented areas.

Non-Ferrous

A paper by W. B. GEORGE (R. Lavin & Sons) discussed the fulfilling of physical property requirements in copper alloy melting. All types of furnace will produce gassed metal if not properly operated, the gas absorption being governed by temperature, furnace atmosphere and time. Melting units for copper-base alloys include: Oil- or gas-fired open flame furnaces; coke-fired crucible furnaces; indirect-arc furnaces, using natural draft or blast draft; and electric indirect-arc furnaces. Oil consumption and melting time data are given. While an oxidizing atmosphere is desirable, slightly reducing atmospheres are usually maintained because of lower melting losses, more easily adjusted burners, and more rapid melting. [This last is highly questionable.—J.W.B.]

E. O. WILLIAMS (Equitable Gas Co.) described certain improvements in stationary and tilting type crucible furnaces and pear-shaped open-flame furnaces that have resulted in nearly ideal mechanisms. Factors contributing to the economies of melting in the crucible type of furnace include the time required to get out a heat, the cost of the fuel, the metal loss, the life of the lining, and the life of the crucible. Furnaces are being built of light weight refractory to cut down heat losses and melting time, and thus save fuel. Two burners are recommended for furnaces up to No. 100 crucible and 4 burners for over No. 100 crucible.

The advantages resulting from the use of modern gas burners in crucible melting were cited by F. L. WOLF (Ohio Brass Co.). These burners result in a quiet operating, stationary, crucible furnace in which perfect combustion and a neutral atmosphere is attained. Gas saving, faster melting and increased furnace life result from the use of these gas burners.

The application of top pouring to non-ferrous castings, such as bushings, pump impellers and pump casings, was discussed by ARTHUR K. HIGGINS (Allis Chalmers Mfg. Co.). Top of riser pouring can be used for castings at the normal pouring rate while common brasses and bronzes could be poured in this manner without drossing in simple castings; also, the size of risers may be materially decreased without having shrinkage extend into the castings.

The increased molding cost resulting from the use of runner boxes has been solved by the construction of core-sand runner-boxes that provide for almost all small castings. Top pouring of 80-10-10, 85-5-5-5, and 75-10-15 non-ferrous alloys permits lower pouring temperatures, thereby enhancing the physical properties of the alloys, produces sounder castings, and reduces the amount of metal needed for gates and risers. WHB (1)

1a. Ferrous

Soaking Pit Practice

"HEATING OF STEEL." PAUL J. MCKIMM. *Steel*, Vol. 106, June 17, 1940, pp. 54, 56, 58, 61, 75; June 24, 1940, pp. 50, 52-53, 56, 59; Vol. 107, July 1, 1940, pp. 52-53, 56, 68. Review plus experiments.

Uniform heating of low-carbon steel ingots is essential to high-quality slabs. A soaking temperature of 2300° F. and a free-cleaning scale layer are highly desirable. Good ingots are, of course, essential and can be produced easily and consistently by normal open-hearth furnace practice.

Higher temperatures and proper soaking greatly improve plasticity, so that greater deformation is permissible without injury to the steel. Soaking time is just as important as temperature; this is true in an ingot where the surface area is heated to a much higher temperature than the core, as well as in an ingot uniformly heated but at a slightly lower temperature than the normal where a temperature difference develops by chilling of the surface through contact with table rollers or excessive cooling water, in which case the core is hotter.

If the core is cooled below certain limits, minute internal fissures will develop, which will cause failure in drawing. If the surface area is cooled, the most common defect is "hair-line" seams; surface chilling is far more detrimental than core-cooling. In rolling surfaces at low temperatures, spreading is promoted, influencing the development of "hair-line" seams and other defects, and the extent of overfill at the roll collar when edge-passing is intensified.

Steels with piping areas, if properly heated and soaked, will yield a commercial product, but if cold, fracturing will result, decreasing the yield. The author has never found in practice a single case of steel being carburized or decarburized during heating in the soaking-pit.

Low-carbon steel can be heated to its

melting point under suitable conditions without damaging its quality. Irrespective of temperature, the only possible way of so-called burning of steel is with oxygen. A test was made at a plant where general practice was to soak thoroughly at 2200°-2300° F. under a smoky condition. Half of a heat was charged to the pits hot, and half cold. Both hot- and cold-charged ingots were heated to various temperatures up to 2740° F. surface temperature. The ingots over 2600° F. had considerable metal washed off, but the slabs that were rolled were excellent with no sign of overheating whatever, either on the surface or in the interior. No difference was noted in quality between the hot- and cold-charged ingots.

To produce a scale layer that is easily eliminated in the early passes, a heating atmosphere sufficiently oxidizing towards the end of the heating cycle should be used. Washing ingots free from scale is not recommended. If scale is not free-cleaning, it will roll in the metal and must be eliminated by suitable means. Too heavy a scale results in excessive loss of metal.

The importance of good heating in hot strip practice is paramount because the slabs must be uniform from slab to slab. The finishing temperature of hot strip controls the physical and microstructural qualities. If a temperature somewhat above the upper critical is maintained and the product cooled on the hot-bed, a microstructure identical with that of normalized stock results. However, if any load, no matter how light, is applied at certain temperatures, the microstructure and physical properties will be affected adversely. MS (1a)

Gray Iron Foundry Progress

A Composite

The recent announcement of the formation of the Gray Iron Research Institute and of its sponsorship of a program of gray iron foundry research at Battelle focusses attention again on the continuing successful efforts of gray iron foundries to better their practice and products. The production of modern high-strength irons was discussed in a digest on "High Test Cast Irons" on p. MA 191 of our May issue; recently-published reviews of general improvements in gray iron foundry practice—advances in equipment and auxiliaries as well as in "metallurgy"—are summarized herewith.

Cupolas and Combustion Control

A comprehensive survey, with 89 references, of improvements in foundry practice from Jan. 1938 to Dec. 1939, is presented by C. H. Lorig & V. H. Schnee of Battelle ("Gray Iron Foundry Practice Moves Forward," *Foundry*, Vol. 68, May 1940, pp. 90-91, 161, 164, 166). No new modifications of the conventional cupola have appeared. The hot blast cupola is reported to be growing in favor in the U. S. A.

The Griffin hot blast process uses heat from the waste gases of the cupola to preheat the air for blast, usually to about 600° F. Coke ratios of 16:1 are feasible for melting temperature of 2650° F., with coke ratio 10:1 for 2800° F. The blast pressure is 8 oz.

In the water-jacketed cupola, the jackets are made of welded steel. One in. split of fire brick protects the jackets and constitutes the cupola lining. In the Moore or Acipco process, the blast is passed through cast iron heating sections set in the cupola wall below the charging door and above the melting zone. The coke ratios here are from 10:1 to 12:1, and the blast pressure for a 72-in. cupola is 14 oz.

In the Italian cupola developed by Olivo separate heating elements in auxiliary wind belts around the cupola are used. Close control of blast temperatures and pressures is claimed. The British balanced-blast cupola has auxiliary tuyeres regulated with the main tuyeres to produce improved combustion, and is claimed to save 30-40% of coke as compared with an equivalent cupola of conventional design. The European Poumay cupola uses auxiliary tuyeres which increase melting rates, with lower coke-to-iron ratios and higher melting temperatures. Tests on the effect of blast pressure in cupola melting indicate that ordinary variations have little effect on the quality of the iron.

Synthetic molding sands are gaining in favor. Their principal fault is a tendency to dry too quickly in large mold work. Studies of dimensional stability of molding sands up to 2500° F. showed that sands varied in expansion on heating from 0.040 in./linear in. to no expansion. To overcome expansion in light castings, the use of high clay content is suggested. Buckling is eliminated by the use of cereal binders.

A new term has been introduced, "working strength" or "toughness", to define the ability of the sand to deform under load. It is expressed as product of deformation and green compressive strength determined on the A. F. A. test specimen used in green strength tests. No conclusive results have been obtained in evaluating the relative merits of clay bonding materials. Core oils are preferable to any other type of binder for cores. High-melting pine wood resin can be used, particularly in sand mixes with high clay content.

In another article, Lorig ("Cast Irons—the Control and Improvement of Their

Properties", *Product Engineering*, Vol. 11, May 1940, pp. 209-212) discusses the improved properties that have resulted from processing advances.

A new combustion control device that measures the relative amount of air entering the cupola and simultaneously records the carbon dioxide content of the effluent gases regulates the blast to compensate for changing conditions in the combustion zone.

Cement-bonded sand (the Randupson process) is coming into wider use for molds for casting gray iron as well as steel and non-ferrous metals. The molds have great mechanical strength and high permeability.

Methods of Improving Strength

Strength has been raised by lowering the carbon content through the use of higher-steel charges or through better cupola regulation. Control of graphite size and distribution by "superheating" the metal from the cupola and by ladle additions of calcium silicide, ferro-silicon, etc. has also improved the mechanical properties of iron castings, although superheating alone occasionally fails to produce the expected strength enhancement. But, provided ladle additions can also be employed, metal heating temperature sometimes influences strength more than do most alloy additions.

Sulphur has been shown to have a profound influence in maintaining the proper structure in the iron. Boyles proved that the dendritic graphite structure of a sulphur-free iron becomes flake-graphite in the presence of some sulphur: increasing the sulphur content causes the flakes to increase in size, reaching a maximum beyond which their size decreases with rising sulphur percentage.

Wear-Resisting Irons

Changes in practice that have led to the improvement of machine tool castings are reported by F. J. Dost of the Sterling Foundry Co. ("Making Better Machine-Tool Castings", *Mech. Engineering*, Vol. 62, May 1940, pp. 365-369). A shift from a 25-50% steel-in-charge iron to a mixture containing 70-95% steel with carbon content lowered to 2.70-3.00% and silicon raised to 1.85-2.25% gave higher strength, higher machinable hardness, excellent finish and less section-sensitivity. Occasionally, however, the wearing surfaces or ways of machines made of this type of iron would score or gall.

Extensive study showed these cases of scoring or galling to be associated with a peculiar structural constituent, called by the author "primary ferrite"—a fine groundmass of ferrite and graphite. [This terminology is unfortunate since the constituent is not "primary" at all.—J.W.B.] This structure, others have shown, tends to occur with (1) high cooling rates, (2) in castings of lower-than-normal carbon content, and (3) in irons heated to temperatures over 2850° F. Late ladle additions were therefore investigated as a means of preventing the formation of so called primary ferrite or limiting it to the very surface of the casting.

Amorphous graphite additions succeeded in reducing the primary ferrite area to a region no deeper than 5/32 in. from the surface. Equally good results were obtained when this treatment was supplemented with ferro-silicon additions. The use of a commercial compound of silicon and carbon also gave a satisfactory structure. Combinations of ferro-chromium and ferro-silicon showed promise.

Control of this type seems to make the difference between a casting that may score and one that will not.

Other Considerations

Further data on ladle additions are given by E. Piwowarsky (Pfannenzusätze für Gusseisen", *Giesserei*, Vol. 27, Apr. 5, 1940, pp. 124-125), supplementing an earlier investigation reported in these columns (May, p. 191; an abridged English translation of this highly important earlier article appears in *Foundry Trade J.*, Vol. 62, May 2, 1940, pp. 325-327; May 9, 1940, pp. 350-352; May 16, 1940, pp. 365-367). The more recent article presents a table of ladle additions developed since 1900, gives the original reference in each case, and indicates specific utility for deoxidation, degasification, nucleation, etc.

Some of the counter-problems that are introduced in following many of the foregoing practices for making high-strength irons are discussed by J. L. Francis ("Production of Pressure-Resisting and High-Duty Iron Castings", *Foundry Trade J.*, Vol. 62, June 20, 1940, pp. 469-471; June 27, 1940, pp. 479-481; Vol. 63, July 4, 1940, pp. 7-10). For example, the high-quality low-carbon irons show a greater shrinkage tendency during solidification, therefore carbon content should be kept as high as possible, consistent with "high-duty" properties. X (1a)

Dry-Blast

"Reminiscences of the First Application of Dry Blast." L. E. Riddle (Carnegie-Illinois Steel Corp.) *Blast Furnace Steel Plant*, Vol. 28, May 1940, pp. 464-470. Review.

James Gayley's dry-blast process was first used at the Isabella Plant on Apr. 11, 1904. The refrigerating apparatus was designed to take 40,000 ft.³ of air/min. at 90° F. and 8.5 grains of moisture/ft.³ and deliver it

at 32° F. and 2 grains of moisture/ft.³ to the engine intakes. With 100% dried air in the blast, 16-20% more ore could be used, with no change in the weight of coke.

During a year on dry-blast, production was 12.4% higher and coke consumption 16.3% lower than during the year immediately preceding and the year immediately following this first dry-blast period, when the furnace operated on natural air. With constant volume of uniform low-moisture air, no reserve heat in the blast was needed, and the maximum available blast temperatures were used by changing stoves every hour. Higher blast heats and more regular work helped dry-blast operation to surpass expectations. With dry-blast, the average of top gas samples showed that carbon monoxide dropped from 24.5 to 23% and carbon dioxide increased from 11.5 to 13.7%.

Other plants were built and proved to be successful. Additional benefits of dry-blast are the more precise furnace control possible, and the more uniform product obtained. The modern installation of Woodward Iron Co. is concerned chiefly with obtaining *uniformity* of temperature and moisture content of air delivered to furnace, rather than obtaining the maximum moisture-reduction possible.

That substantial economies result from the application of dry-blast even in periods when atmospheric humidity is relatively low is demonstrated by the results of work on two furnaces of the same dimensions, side by side, one on natural air and the other on dry-blast, during a winter month when the moisture in the natural air was below 2.5 grains during the whole month. On one of the furnaces with dry-blast, when operating for fuel economy, the ore burden was increased 19% with the same weight of coke, production increased 5.4%, coke consumption decreased 22.6%, air-supply revolutions dropped from 111 to 96, and temperature increased from 716° to 802° F.

Comparison of the effect of humidity over a long period is misleading as it does not take into effect the day-to-day fluctuations. With dry-blast, it is unnecessary to manipulate blast temperatures and volumes to compensate for these daily variations. MS (1a)

1b. Non-Ferrous

Electro-Refining Progress

"Progress in Electrolytic Refining of Metals, with Special Reference to the Last Decade." Max F. W. Heberlein (U. S. Metals Refining Co.) *Trans. Electrochem. Soc.*, Vol. 77, 1940; Preprint No. 25, 11 pp. Review.

Progress in the refining of copper has been mainly mechanical. Concrete tanks have been substituted for wooden tanks as refining cells. Economy in power consumption has been attained by reduction of current losses and contact resistance, and by better design of bus-bars, hangers, anode ears, etc.

Copper is recovered electrolytically from brass or bronze scrap which is cast into anodes and used in a cuprous chloride or copper sulphate solution. Methods of electrorefining lead-bearing copper and copper high in silver (about 20% Ag) have been developed. One of the developments in the treatment of anode slimes is the recovery of selenium and tellurium, which have found increased industrial uses in recent years, and which occur in the copper of Canada and Sweden. The selenium may be recovered from slimes by volatilization, by roasting and then leaching with caustic soda solution, or by roasting with caustic soda and then leaching.

The recovery of the precious metals has not been basically changed, but modifications have been introduced to cope with local conditions. For example, the Boliden Co. refinery in Sweden avoids the customary Doré smelting; superimposed alternating and direct current is used for electrolytic refining of gold in an Amsterdam plant; an Australian plant refines gold with chlorine gas instead of by electrolysis. Electrolytic methods for recovering silver and gold from precious metal scrap have been developed.

The advances in the electrolytic refining of lead are mainly mechanical in nature. Electrolytic solder is produced by the U. S. Metals Refining Co. by electrolyzing with anodes of white metal scrap in a fluosilicate bath. The deposit is afterwards blended to specifications. There has been little progress in the electrolytic refining of tin.

The most widely used method of electrorefining bismuth employs a chloride electrolyte containing 100 g/l. of free hydrochloric acid. A fluosilicate bath has advantages, but is more expensive. Antimony is electrorefined in a bath containing free sulphuric acid and hydrofluoric acid. While the use of hydrofluoric acid was proposed in 1915, it was only relatively recently that equipment was introduced that could resist the corrosive solution.

The improvements in the electro-refining of nickel relate mainly to the treatment of platinum-bearing anode slimes. Electrolytic manganese is now produced in Tennessee; this process is one of electro-winning rather than electro-refining. AB (1b)

Processing and Fabrication

2

FORGING, FORMING, MACHINING
HEAT TREATMENT, WELDING, FINISHING

Drop and Hammer Forging, Drawing, Extruding, Stamping and Machining. Age-Hardening, Annealing, Carburizing, Hardening, Malleableizing, Nitriding, Surface-Hardening and Tempering. Heating Furnaces, Refractories, Fuels and Auxiliaries. Welding, Flame-Cutting, Hardfacing, Brazing, Soldering and Riveting. Cleaning, Pickling, Electroplating, Galvanizing, Metallizing, Coloring and Non-Metallic Finishing.

Recirculating Furnace Gases

Return of Combustion Gases in Furnace Installations, Particularly in Gas-Fired Industrial Furnaces ("Rauchgasrückführung in Feuerungsanlagen, insbesondere in gasbeheizten Industrieöfen") A. R. Leve. *Gas- u. Wasserfach,* Vol. 83, Apr. 6, 1940, pp. 157-161; Apr. 13, 1940, pp. 173-176. Investigation.

The quantitative extent to which recirculation of the gaseous combustion products in a furnace can improve its economy and efficiency was determined. The return of the waste gases to the system can be accomplished (1) by mixing with the combustion air, (2) by mixing with the gas in the burner, or (3) by mixing with the fresh fuel gas.

For metal-heating furnaces of the gas-fired type, adding the hot combustion products to the air-gas mixture at the burner is satisfactory, and mixing with the fresh fuel gas most desirable. The accompanying table, based on experiments, shows the savings that are possible for different gases (with and without preheated air) as compared with furnace operation in which combustion products are not recirculated.

The gas in all cases was burnt with the theoretical amount of air, for which case the economy is the highest; if an excess of air is necessary because of operating conditions, the saving will be less, but still substantial in many cases. Ha (2)

Per Cent Saving with Recirculation as Compared with Ordinary Furnace Practice

Fuel Gas	Temperature of Preheated Air, °F.	Per Cent Saving in Fuel Cost, with Circulated Combustion Products at 400° F.	750° F.	1100° F.	1500° F.	1800° F.
Producer Gas	not preheated	0.9	1.7	3.1	4.9	8.0
	400	10.0	12.0	14.7	18.4	24.1
	750	18.9	21.5	25.0	29.7	36.8
Water Gas	not preheated	2.9	7.0	12.4	19.2	28.9
	400	7.9	12.4	17.8	25.1	34.7
	750	13.4	17.7	23.4	30.9	40.2
City Gas	not preheated	2.9	6.8	12.0	18.8	28.5
	400	8.5	12.8	18.2	25.5	35.0
	750	14.1	18.5	24.2	31.5	41.0
Coke Oven Gas	not preheated	1.9	6.5	11.1	17.6	26.1
	400	7.3	11.7	17.4	24.2	32.8
	750	12.9	17.8	23.8	30.6	39.6
Natural Gas	not preheated	2.4	6.0	10.6	17.0	26.0
	400	8.6	12.5	17.6	24.2	33.5
	750	14.9	19.0	24.3	31.2	40.5

Welding Silicon Bronze to Steel

"The Silicon Bronzes." Harold Lawrence. *Steel,* Vol. 106, June 3, 1940, pp. 67-68. Practical.

Silicon bronzes do not have quite the strength of steel nor do they have a definite yield-point as high as that of the usual boiler and tank steel. However, they have been accepted by the A.S.M.E. code for fabrication of pressure vessels and, therefore, much interest is attached to methods of welding them. The carbon-arc method is in almost universal use for welding silicon bronzes, with metallic arc welding used in some instances.

In joining silicon bronze and steel, an extremely hard and brittle complex is formed when the two mix. The plates to be welded must be very clean. Next, the flux (either 90% borax, 10% sodium fluoride, or a paste of sodium fluoride, barium carbonate, fused borax, and manganese boride in methyl alcohol) is applied sparingly by sprinkling on when the joint has become quite hot.

A proper overlay of silicon bronze must be placed on the steel surface before the two metals are welded together. This overlay may be applied with either the carbon-arc or the oxyacetylene torch; the latter permits better control. The two parts to be welded are then brought together, the flux is applied, and the parts are tack-welded together. More flux is put over the tacks and welding follows.

The carbon-arc is played on the silicon bronze side of the joint as much as possible. Unless the arc is controlled carefully, steel pickup will occur. The weld is completed the same as any other weld joining silicon bronze to silicon bronze. MS (2)

Electropolishing

A Composite

Metallurgical engineers show continually increasing interest in the special advantages of electrolytic polishing for bright-finishing many commercial products made of a variety of metals. Electropolishing permits the production of luster on surfaces that are inaccessible to mechanical polishing or the mechanical polishing of which for some reason or other is expensive.

The general background of electropolishing and its current commercial status have previously been discussed (see "Electrolytic Polishing" on p. MA 23 of our Jan. 1940 issue, and "Commercial Electropolishing of Stainless Steel" in Feb., p. MA 88). More recently, additional articles have appeared, devoted to the mechanism, scope and usefulness of electrolytic polishing in general, the merits of certain individual processes, and the particular value of this new art for finishing wire and wire products.

Scope

Comprehension of the differences between mechanical and electrolytic polishing methods is necessary to appreciate fully the nature of the electrolytic product, say H. Pray & C. L. Faust of Battelle ("Comments on Electrolytic Polishing of Metals," *Iron Age,* Vol. 145, Apr. 11, 1940, pp. 33-37). In mechanical polishing the high spots or elevations are removed, or caused to flow, until a substantially flat surface results, which then has a "pseudo-amorphous" layer of worked metal. In electropolishing, the surfaces of the grains are rendered substantially level and highly lustrous without distortion, and with some surface passivation.

The electrical requirements are similar to those for ordinary chromium plating. Current density is important but not always critical. The *minimum* current density seems more significant than the *maximum* in a given case, and processes with low minima are more desirable than those with high. Voltages, in general, are of the same order as chromium plating; the use of 12-volt generators provides advantageous flexibility.

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To be successful, baths and operating conditions must be tailor-made for the metal or alloy being finished as well as for its form and shape. The life of contact materials and racks is an important operating factor. Thus, one bath has been developed that successfully polishes stainless steel but in which copper is so polarized that copper racks and bronze contacts give long life.

Electro methods are not cure-alls. One cannot start with a rough sand casting and obtain a smooth mirror-like finish, although electropolishing the sand casting will produce a brilliant rough surface that cannot be obtained mechanically. Markings that are merely manifestations of cold working in forming are easily and rapidly removed but actual scratches can be removed only if not too deep. Electropolishing is a *finishing* rather than a *roughing* operation. In many cases of metal finishing, electropolishing alone will suffice; in others it should be used in conjunction with mechanical buffing.

Mechanism

When metals are subjected to anodic treatment, a surface film may form and thus disturb the normal anodic solution process. If the film is non-conducting and only partly covers the anode surface, the free portion of the surface will be dissolved at locally higher current densities if the same total current is maintained. Polishing results from this selective removal of tiny elevations on the metal surface, effected when depressions are anodically passive and elevations anodically active.

The exact nature of the anodic film need not be defined, since its function is the same whether it be an oxide, a gas layer, a film of insoluble anodic product or a static liquid film highly concentrated in anodic products. SAM TOUR, of Lucius Pitkin, Inc. ("Electropolishing," *Metal Finishing*, Vol. 38, June 1940, pp. 308-312) examines all these theories plus an additional one—that certain materials in the electrolyte act as inhibitors and thus produce a polished rather than an etched surface. Reagents successfully used for metallographic electropolishing are not necessarily adaptable for large scale operation.

Some Individual Processes

In the article just cited and more intensively in another ("Pickling and Polishing of Metals," *Iron Age*, Vol. 145, May 23, 1940, pp. 56-60; May 30, 1940, pp. 26-30) TOUR reviews the various electropolishing processes that have been proposed in the periodical and patent literature since 1915, presenting what looks like a complete source list. Special merit is implied for the new Blaut-Lang process, in which is employed a bath containing a mixture of phosphoric and sulphuric acids, used at 180°F. A current density of 2-4 amps./in.^{2} is used for flat stock and 5-10 amps./ft.^{2} for wire.

Times of treatment vary according to the condition of the surface—2-4 min. for flat stock, and 6-12 min. for curved. Voltages range from 6 to 12 v. Cathodes are of lead or copper and the work racks of copper. Nickel, Monel, Inconel, aluminum and its alloys and plain carbon steel, as well as stainless steel have been successfully treated by this process.

Rustless Iron & Steel Company's process for stainless steel is described in detail by A. L. FEILD & I. C. CLINGAN ("Chemical (*sic*) Polishing Method," *Steel*, Vol. 106, Apr. 22, 1940, pp. 54, 56, 64). In this case the electrolyte is composed of citric acid (30-70% by weight), sulphuric acid (10-30%) and remainder water. Longtime operation of these baths is possible because neither of the acids is volatile; some solutions have been in continual service more than a year and are still operating satisfactorily. Hoods and ducts are unnecessary.

The solution is less severe on contacts and racks than others that have been proposed. A copper-silicon alloy is preferred for contact materials. Work racks are coated with a chromium-rubber compound. Operating temperature is 180°-190° F. (self-maintained), voltage 6-9 v., and current density 1 amp./in.^{2}

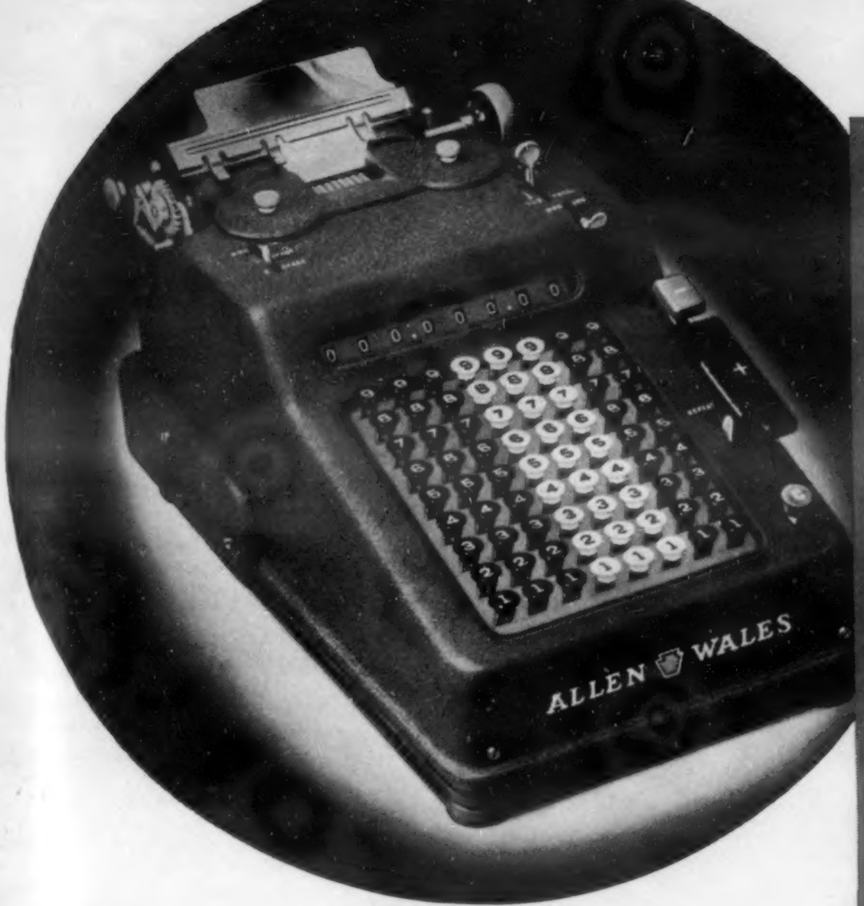
Some general comments on the electropolishing of wire and wire products, and processes therefor, are given along with other things by C. L. MANTELL (Electrolytic Cleaning, Pickling and Polishing of Wire and Wire Products," *Wire & Wire Products*, Vol. 15, Aug. 1940, pp. 413-415). X (2)

Slip, Cold Work and Aging

"REPORT OF A CONFERENCE ON INTERNAL STRAINS IN SOLIDS" (Held at Univ. of Bristol). *Proc. Physical Soc., London*, Vol. 52, Jan. 1940, pp. 1-178. Survey.

The papers read at this conference, with the reports of the ensuing discussions, comprise a valuable up-to-the-minute account of the latest ideas on the structure of metal crystals and the mechanisms of slip and cold work.

In Part I, on "Slip in Metal Crystals", E. N. DA C. ANDRADE suggests a generalization to explain why metals of the same crystal system do not always slip on the same glide planes. In any crystal, the *direc-*



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tion of glide is fixed by the most closely packed line in the lattice system, but the *plane* of glide is determined by the temperature and may be affected by minor impurities or disturbances of the lattice.

E. OROWAN stresses the importance of considering creep phenomena in any theory of plastic flow. The discrepancy between the theoretical and actual strengths of metal crystals is, of course, discussed and some interesting evidence put forward to indicate that "dislocations" really exist in a crystal lattice. An iron wire may, through the phenomenon of "yielding", actually appear to soften under strain and, if it is bent around the finger, will continue to bend at the points where bending began, and will form a polygonal ring. A copper wire, on the other hand, will bend at the points that have suffered least deformation, and will take up a continuous curvature. Strain softening in iron can be attributed to imperfections in the lattice.

R. PEIERLS calculates that the dimensions of a dislocation are not appreciably larger than the distance between atoms. In the discussion, W. L. BRAGG suggests a new mechanism of slip by which whole planes, instead of lines of atoms, slip into new positions simultaneously.

In Part II, on "Precipitation in Metals and Age Hardening", R. M. BARRER gives a summary of the available data on diffusion constants which emphasize that diffusion must precede age hardening, and R. BECKER attempts to calculate the rate at which nuclei form in an "undercooled" solid solution. Calculations of the distribution of the internal strains produced by precipitation are made by N. F. MOTT and F. R. N. NABARRO.

Part III deals with "Polycrystalline Metals and the Effect of Cold Work". W. L. BRAGG introduces a new conception of the structure of cold-worked metals by suggesting that the boundaries between the "crystallites" into which the lattice are broken are not frozen in position but may wave about. Thus, a metal will readily self-anneal to a certain coarseness of crystallite size but later the process becomes so slow that the metal is in an approximately constant condition.

BRUCE CHALMERS discusses the effects of grain boundaries on the mechanism of slip and concludes that the presence of a number of adjacent crystals may modify the glide characteristics of a single crystal. Finally, in Part IV, excellent reviews are included by R. BECKER and CLARENCE ZENER on magnetic phenomena and internal friction in solids, respectively. JCC (2)

2a. Ferrous

What's Weldability?

"ABSTRACT SYMPOSIUM ON WELDABILITY." *Welding J., N. Y.*, Vol. 19, Apr. 1940, pp. 146s-160s. Several papers presented at the annual meeting of the Am. Welding Soc. at Chicago, Oct. 23, 1939.

Basically, the purpose of this roundtable meeting, according to M. F. SAYRE, its chairman, was not to arrive at any conclusions with regard to weldability, but to present suggestions, indicate work that is under way show the direction in which further work should be done, and report on progress generally.

Definitions

A piece of steel, says C. A. ADAMS, is said to be weldable when it can pass through the heat cycle of a normal welding process without developing a serious tendency to crack. The tendency to crack depends upon two things—the residual stresses of welding and the ability of the metal to withstand these stresses without cracking, namely the ductility.

Weldability seems to be an omnibus term in the same general class as forgeability, drawability, workability, machineability, and hardenability, J. H. CRITCHETT points out. Each term would have a different connotation, in all probability, in the minds of each practitioner. Given suitable design and freedom to use any welding process and special technique, including preheating and subsequent heat treatment if desired, the statement that all steels are weldable cannot be challenged.

Basically, all tests for weldability depend on putting the material through the temperature cycle involved in welding and applying a test for ductility. The weldability of steel is that *set of properties* that permits mechanically continuous surface bonding without undesirable change in the physical properties of the adjacent material as a result of the conditions correlative to effecting this bond.

Current Test Methods

As a reliable gage for this "metallurgical damage", the notch impact test made on samples of steel heat-treated to duplicate the critical zone next to the weld is suggested by W. H. BRUCKNER. The weld quench tests are regarded as a short cut to the information on reaction rates that the determination of the Bain S-curves for the steels would give.

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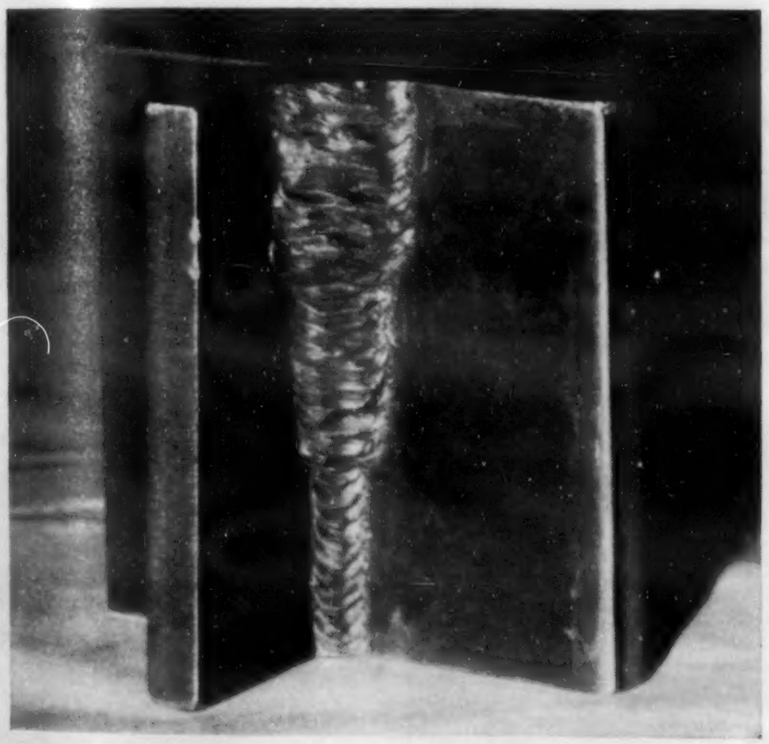

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GENERAL ELECTRIC

ing the weldability of a steel is described by A. G. Bissell. Whether a steel is weldable depends on the specific conditions under which the welding operation will be performed. The physical condition of the steel as well as its chemical composition is an influencing factor. Specimens for this test consist of two pieces of the material under test joined together by fillet welds. The test specimens are saw-cut from the assembly. The tongue of the T is wedged in the slide of a jig which holds the specimen securely, preventing any side or end movement and forcing bending to occur uniformly at the toe of each fillet when pressure is applied to the back of the specimen.

The angle of bend at maximum load is recorded. Bending is continued to the capacity of the jig and the condition of the specimen is noted when failure occurs. A steel with a high angle of bend at maximum load and one that will pass through the jig without cracking is considered first class for welding.

The Navy program in seeking a weldability test is discussed by Clarence E. Jackson. Full automatic control of welding conditions is fundamental in making test welds. In the present phase of the investigation, about 35 hot-rolled laboratory and commercial steels of plain carbon and low-alloy types are being studied. Considerable data have been collected on this group of steels as hardness, weld-quench, bead-weld, V-notched bars, and T-bend specimens have been prepared.

The bead-weld V-notched bars were prepared from single bead welds on ½ in. thick plates. The apex of the V-notch was machined tangent to the fusion line. Good correlation is possible between the results of the Charpy V-notched-bar test and the T-bend test. However, the results of either of these tests cannot be correlated with the data obtained with the weld-quench or with hardness measurements. A "good welding steel" is one that is tough and retains its toughness under the influence of the weld heat treatment.

The general problem of weldability, thinks W. L. Warner, is that of determining whether a structure can be built with a certain material. This problem involves three distinct fundamental divisions: The effect of the heat of welding on material to be welded; the nature of the welded joint; and the weldability of the *design*. These problems cannot be answered by a laboratory test.

Weldability is defined by J. C. Hodge as the ability of the steel to pass through the thermal cycle of a particular welding technique without the production of hard or brittle zones in the welded joint, which would tend to the production of cracks or to the failure of the welded joints under service loading. Our present knowledge does not go far beyond the facts that (1) for easy weldability an approximate limit of 0.35% C is advisable, and (2) higher carbon contents imply greater restrictions in welding. A test for relative weldability consists of judging the performance of simple bend specimens having a bead deposited on the outer surface of the specimen.

S-Curves and Cooling Rates

Along these lines C. A. Adams points out that the higher the rate of cooling, the higher the residual stresses and also the greater the tendency toward a brittle martensitic structure in the heat-affected zone. The rate of cooling of a particular zone is inversely proportional to the heat delivered to that zone and directly proportional to the heat dissipating power. It is suggested that future work aim at the development of a method to predetermine the rate of cooling by theoretical calculation aided by experimentally determined coefficients.

S-curves for all the steels concerned will thus be needed. Given this information, it would be the work of only a few minutes to estimate with fair accuracy the crack tendency in a new set-up or to prescribe the welding technique that would eliminate the danger of cracking.

Examining this suggestion, E. E. Thum stressed the large number of variables involved, and the need for considerable mathematical ability to evaluate the general equation. Even after the geometry of the joint has been solved and the heat input and heat extraction have been carefully mapped out, the hardenability of the specific piece of steel used and the toughness of its various hardened stages are still important problems. It therefore should be easier to integrate all these variables at once by making a joint by a commercial process and technique and then comparing the properties of that joint with the properties of the original metal.

According to Bela Ronay, tests under way indicate that classification of steels as to weldability may have to be expressed as a function of (a) the geometry of the joint, (b) the power input (the minimum size electrode permissible to weld a given plate thickness for each type of joint), and (c) the position of the joint. All his welding tests are performed by means of an automatic welding apparatus capable of precision performance in all positions.

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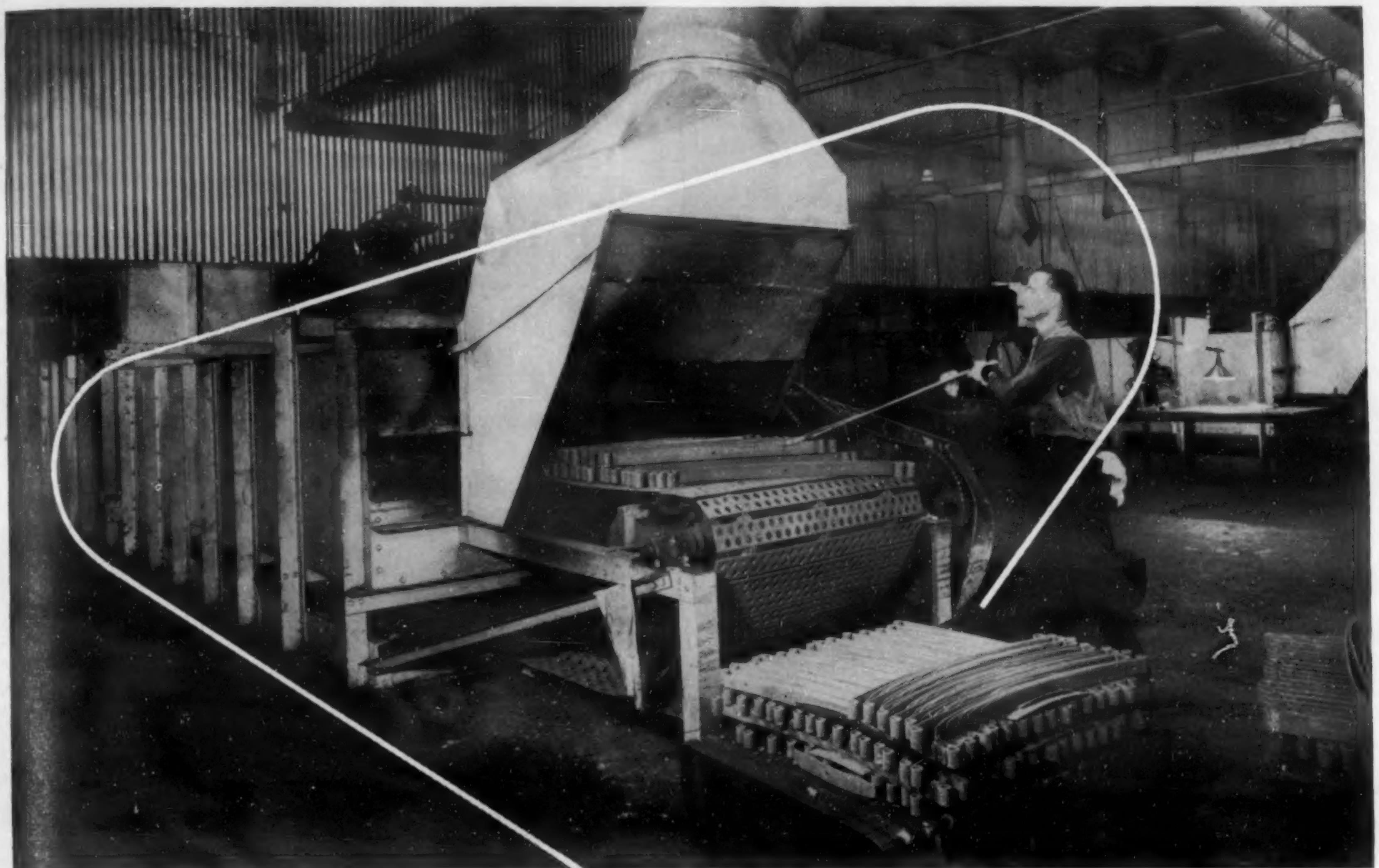

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The "closing remarks" of the Symposium are presented by S. L. HOYT. Given the cooling rate and curve for an arc-welded joint, the problem, as he sees it, is that of ascertaining what metallurgical factors determine the weldability of a steel under those conditions. There are several methods of attacking this problem, but the one utilizing the well known S-curve is certainly worthy of consideration. The weldability of a steel is directly related to the S-curves of beginning and ending transformation to pearlite.

An important contribution to the problem of the weldability of steels would thus be made were we to have the S-curves for those steels that are important to the welding art. In addition, actual welding conditions should be regarded as just as vital to the general problem of weldability as are the metallurgical characteristics of the steel being welded.

[*A complete answer to the problem of weldability and testing methods, therefore, is not contained in this symposium. The consensus seems to require the retention of ductility of the base material after being subjected to the welding thermal cycle. It would be Utopian to end the search for a weldability test with a testing procedure as detailed as that suggested by Adams and Hoyt; as simple as that suggested by Hodge or Warner; and still as close to practice as that suggested by Thum, Rucquoi or Critchett. Reports of further research will be essential in order to achieve the final goal for a practical, flexible, and critical test for weldability.—C.E.J.*]

CEJ (2a)

Oxygen Cutting of Steel

"OXYGEN CUTTING OF STEEL, PART II—OXYGEN CUTTING PROCEDURE. A REVIEW OF THE LITERATURE TO JAN. 1, 1939." W. SPRARAGEN & G. E. CLAUSSEN (Welding Res. Comm.) *Welding J., N. Y.*, Vol. 19, May 1940, pp. 161s-208s. Correlated abstract, 333 references. For Part I, on "Mechanical Properties and Metallurgy," see METALS AND ALLOYS, Vol. 10, Oct. 1939, p. MA 606 L/8.

The lowest oxygen consumption per unit length for a given thickness is secured under conditions that utilize the maximum amount of oxygen as iron oxide. In the interest of economy, the drag (the distance the bottom of a cut lags behind the top or torch side) should be as long as possible without leaving objectionable uncut corners. If the speed of cutting is increased, the hourly oxygen consumption for a given tip diameter and drag is nearly proportional to the speed of cutting, which applies to drag not too near the minimum and to speeds not too near the maximum possible.

Oxygen Consumption

Impurities in the cutting oxygen have a bad effect on cutting speed and oxygen consumption per unit length. Several investigators have recommended torch adjustments and cutting speeds applicable for low-purity oxygen. Although nitrogen was the major impurity present in the oxygen used by most investigators, there seems to be no appreciable difference if the impurity is water, hydrogen or carbon dioxide in the amounts investigated. Acetylene purity is relatively unimportant in oxygen cutting.

The recommended tip size increases with increase in thickness. Increasing the tip size raises the cutting speed at the expense of oxygen consumption and width of kerf. Other conditions remaining the same, a decrease in tip size greatly increases the drag. Increase in pressure and decrease in cutting speed reduce the drag. Cutting speed had little influence on oxygen consumption per unit length with the thinner plates, but with plate 2 in. thick oxygen consumption per unit length decreased in direct proportion as cutting speed was increased.

Preheating

For all relatively thick material, preheating flames are required to maintain uniformly high-speed cutting. Most authorities recommend a neutral flame with the cutting-oxygen valve open. Since the maximum oxyacetylene flame temperature is reported to be attained at an oxygen-acetylene ratio of 1.46 or 1.7 to 1, it is natural to expect that the preheating time will be shorter for an oxidizing flame than for a neutral flame.

The proportion of the total heat evolved in oxygen cutting thus supplied by the preheating flame may be greater than 50% in steel less than ½ in. thick, but less than 10% in steel 6 in. thick. The acetylene consumption per unit length required to produce smooth cuts increases linearly with the thickness and is nearly independent of the diameter of the cutting orifice. The consumption of the cutting oxygen per unit time is completely independent of the intensity of the preheating flame.

It is common practice to preheat higher carbon and alloy steels at 575°-1100° F. to prevent hardening and cracking during oxygen cutting. In addition to its metallurgical effects, preheating reduces the oxygen consumption per unit length of cut. In one case, with an oxyhydrogen torch, the cutting speed was increased 26-38% and the oxygen consumption was reduced 23-41% by preheating steel 0.79-1.57 in. thick to 1100° F.

A great many fuels may be substituted for acetylene in oxygen cutting, but apart from cost, which is essentially a local consideration, there is scant technical basis for their preference over acetylene. Hydrogen, though, is preferred for under-water cutting and is advantageous for heavy cuts from 20 to 40 in. thick. Again, oxygen - city gas cuts in thin material are likely to be smoother and sharper than oxyacetylene. Good commercial cuts can also be obtained with propane provided suitable torches and proper technique are used; in one application—rusty parts or scrap—advantage is claimed for the propane because there is less back-firing.

Best Practice

The quality of the lower edges of a cut is determined by the oxide that flows from the kerf, and the manner in which the slag flows from the kerf is an indication of conditions during heavy cutting. Good cutting procedure produces a fan-like spray of sparks, hugging the bottom surface, drooping at the outer edges and issuing from the leading edge of the kerf in a forward direction and to both sides. Just to the rear of this spray of sparks is the heavy slag, clinging to the bottom of the cut and lazily dropping in large globules.

The width of the kerf is the distance between the two surfaces of the cut. Under favorable conditions, the kerf width is constant at all sections through the thickness. Kerf width is a measure of the amount of iron removed by the cutting jet and must be known in advance for precision cutting. The rule-of-thumb allowance for kerf width in machine cutting is 1½ to 2 times the diameter of the cutting orifice for thicknesses over 6 in. For thinner material the kerf width may be assumed the same as the diameter of the cutting orifice.

The conditions required for most economical oxygen cutting are: (1) Drag no shorter than is absolutely necessary; (2) as small a tip as possible, even at the sacrifice of cutting speed; (3) oxygen pressure so high (consistent with the assigned drag) that either (a) additional pressure and speed yield no greater economy, or (b) additional pressure grooves the cut excessively. The relationships will depend on the relative costs of the gases. CEJ (2a)

Stress Relief of Welded Pressure Vessels

"How Thermal Stress-Relieving Reduces Residual Stresses." Harold Lawrence. *Welding Engr.*, Vol. 25, April 1940, pp. 19-21, 23. Review.

Residual stresses occur in welded structures both as the result of contraction of the weld metal and as the result of the expansion and contraction of the base metal because of the heat effect of welding. Mechanical stress-relief has been frowned upon by American pressure vessel manufacturers although European practice has adopted the procedure rather widely. Engineers in this country feel that too many places exist in pressure vessels where mechanical stress-relief may be had only at the expense of overstressing portions of the weldment that carry only a minor portion of the service load.

Residual stresses equal to the yield strength of the weld metal and base metal exist and should be considered in every weldment. No one can tell when the summation of all the stresses on a structure takes that structure beyond the region of plastic flow where a small increment of load may lead to rupture. As the temperature of mild steel is increased, the yield point decreases. From an original value of 30,000 lbs./in.^{2} at ordinary temperatures, the yield point of low-carbon steel falls below 10,000 lbs./in.^{2} at 1200° F.

The majority of the thermal stress-relief treatments of such steel take place between 1100° and 1250° F. The residual stress in the steel falls to the value of the yield point at the maximum temperature reached, provided all temperatures are slowly increased and slowly decreased so as to not introduce new residual stresses. [*Temperature high enough to cause structural damage must also be avoided.—C.E.J.*]

Preheating and peening may be employed to reduce the intensity of residual stresses resulting from welding operations. The sequence of welding has an important bearing on the amount of locked up stresses. Since the cost of the stress-relieving operation is such a small fraction of the total cost of the finished product, every pressure vessel manufacturer should be able to put that extra amount of quality into his product. CEJ (2a)

Hydrogen in Electroplating

"Metallurgical Aspects of Hydrogen in Electroplating." C. A. Zapffe & C. L. Faust (Battelle Mem. Inst.) *Proc. Am. Electroplaters' Soc.*, June 1940; Preprint, 20 pp. Review plus research.

The absorption of hydrogen in steel is the cause of some common defects in electroplating and enameling, such as embrittlement, peeling, blistering, pitting, etc.

Hydrogen dissolved in steel is atomic and the amount dissolved is proportional to the square root of the pressure. The solubility of hydrogen in iron decreases rapidly with fall of temperature; below 750° F. the solubility is very low. When iron is cooled, hydrogen precipitates at discontinuities, and often the pressures developed are sufficient to rupture the metal and produce "flakes", shatter cracks, and "fisheyes".

Hydrogen evolved by pickling or cathodic treatment diffuses into steel and may be trapped as molecular hydrogen at grain boundaries, slag inclusions, microscopic rifts, at the interface between the steel and a coating, or even in the slip planes of a crystal. Hydrogen embrittlement may result from the strain imposed by the occluded hydrogen or by hydride formation. Experiments are given showing how hydrogen can force enamel, paint, or metallic coatings from steel.

The efficacy of pickling in removing scale is partly dependent on the solution and diffusion of hydrogen in the steel. The hydrogen subsequently precipitates beneath the scale and forces it loose. Blisters produced on sheet steel by pickling are the result of hydrogen being precipitated at the site of slag inclusions. The amount of hydrogen occluded by sheet steel is increased by cold working and by increase of sheet thickness. Pickling at elevated temperatures increases hydrogen absorption; therefore elevated temperatures are detrimental unless the time can be considerably shortened.

Pickling in hydrochloric acid produces less hydrogen absorption than in sulphuric acid. Inhibitors are useful for decreasing absorption of hydrogen, but are effective only below certain temperatures. Comparing conditions that liberate equal quantities of hydrogen in equal intervals of time, steel absorbs less hydrogen in cathodic electrolysis than in acid pickling.

The presence in the bath of small quantities of elements of the 5th and 6th groups of the Periodic Table considerably increases the hydrogen absorption of steel. Small quantities of arsenic can increase hydrogen absorption 100-fold. In electroplating, gas pits may result from the continual escape of hydrogen trapped at discontinuities in the base metal. AB (2a)

Flame Hardening Malleable Iron

Flame Hardening of Cast Iron and Malleable Iron ("Autogenes Härten von Gusseisen und Temperguss") G. Kritzler. *Z. Ver. deut. Ing.*, Vol. 84, Mar 2, 1940, pp. 148-150. Review plus research.

Heat treatment by annealing, quenching and tempering considerably increases the durability of cast iron. In the surface hardening of cast iron, decarburization of the embedded graphite is fairly difficult, but experiments have shown that the temper-carbon-bearing structure of malleable iron (blackheart) can easily be retransformed into simple ferrite.

According to the intended purpose of the material, three basic hardening possibilities exist: (1) The production of pearlite and sorbite by partial solution of the temper carbon in austenite and suitable cooling; (2) production of martensite by rapid cooling from the austenite temperature; and (3) production of cementite by recarburizing large amounts of temper carbon at high temperature and rapid cooling. The so-called cementite hardening is important as it confers heat resistance up to about 500° F. It is, therefore, advantageous, for example, for high-speed engine crankshafts.

Malleable iron samples of 0.6 in. diam. (analysis: 2.17% C, 1.05 Si, 0.25 Mn, 0.061 S and 0.050 P) were heated with the oxyacetylene flame, using the type of burners employed for steel sheet, to 1475°-2200° F. and quenched in either water or oil. The heating times were very short, between 12 and 23 sec. The hardness reached a maximum of 530 Brinell for quenching temperatures between 1800° and 2000° F. for small heating velocities. The structure corresponding to this hardness maximum consists of martensite.

From the higher temperatures cementite, with lower hardness but better heat resistance, is formed. With greater heating velocities, the maximum hardness is not attained until quenching temperatures of 2000°-2200° F. are reached. Quenching with oil gave slightly better values. The hardness values for slow heating were, for all quenching temperatures, somewhat better than for faster heating; the effect of heating velocity diminishes at the higher quenching temperatures or for the high hardnesses. Ha (2a)

Deep Drawing of Mild Steel as Affected by Aging

"Quench Ageing, Strain Ageing and Cold Working of Steel." J. H. Andrews, J. W. Rodgers, H. A. Wainwright & J. N. Blackhurst. *Sheet Metal Inds.*, Vol. 14, Apr. 1940, pp. 389-393; May 1940, pp. 505-507. One of several papers in the recent Deep Drawing Symposium of Inst. of Auto Engrs. (British)

Quench aging (hardening on room-temperature storage after quenching) seems to

be due to retention of some unstable low-carbon austenite. Strain aging (hardening on aging after severe cold work) of a steel results in a hardness increase about 1/3 that brought about by quench aging. Sometimes both tensile strength and elongation increase simultaneously during this aging. Cold-rolled-and-normalized steel hardens more than cold-rolled-and-annealed steel on aging.

Pressing tests were carried out to determine the relationship between aging and deep drawing of dead mild steel strip. Out of the large number of variables affecting the pressing operation, certain ones were studied: Blank holder pressure (not very sensitive to metallurgical changes in strip), depth of draw (fairly sensitive, but gives little more information than Erichsen test), and aging. Other variables, considered to be less important, were: Blank diameter (perhaps most sensitive, but not easily made main variable with blanking and forming tool), degree of cold reduction (here used only incidentally to cause aging), lubrication, speed, heat treatment and microstructure.

Tests were made on a rimming steel with 0.06% C, 0.30 Mn, 0.031 P, 0.033 S, 0.006 Si; the hot rolled strip (0.080 in.) was cold rolled to 0.036 in., then annealed for 12 hrs. at 1250° F. The most sensitive form of test, apart from the variation in blank diam., is the depth of punch; variation in blanking pressure is not sufficiently sensitive. There is a falling-off in drawability as aging proceeds.

The effect of annealing was studied with 5 in. diam. blanks, 40 lbs./in.^{2} blank holder pressure, and speed of 71 strokes/min.:

Treatment	*Max. depth of punch*
1250° F., 12 hrs.	43
1375° F., 3 hrs	47
1375° F., 3 hrs., cooled to 1250° F., held 4 hrs., then heated to 1375° F. for 3 hrs.	48
1375° F., 8 hrs.	43

Hardness tests on cups showed that the hardness is a maximum where there is a piling-up of metal, while there is little or no change at the base of cup.

Mechanical properties were determined on annealed and on quenched steel cold-worked and aged to varying degrees. The elongation values (% in 2 in.) obtained were as follows:

Treatment	*Elongation*
Annealed, cold-rolled 5%, aged 20 min.	37
Annealed, cold-rolled 5%, aged 3,000 hrs.	28
Annealed, cold-rolled 40%, aged 20 min.	4.5
Annealed, cold-rolled 40%, aged 3,000 hrs.	2.0
Water-quenched from 1175° F., aged 7 weeks, rolled 5%	9.0
Water-quenched from 1175° F., aged 7 weeks, rolled 40%	3.2
Water-quenched from 1175° F., rolled 5%, aged 7 weeks	14.0
Water-quenched from 1175° F., rolled 40%, aged 7 weeks	7.7

Changes in hardness caused by aging cylindrical pressed cups were followed. The results were erratic and showed the non-uniformity of pressing conditions on similar parts of cup. There was a uniform aging effect, however, over the whole width of the flanges. The aging seemed to be independent of the degree of deformation.

JZB (2a)

Hardenability and Grain Size

"Influence of Austenitic Grain Size on the Critical Cooling Rate of High-Purity Iron-Carbon Alloys." Thomas G. Digges. *J. Res. Natl. Bur. Standards*, Vol. 24, June 1940, pp. 723-742. Research.

A method is first described for heating small specimens *in vacuo* and in an atmosphere of dry nitrogen to different temperatures and quenching directly in hydrogen. Determinations were made of the austenitic grain size and critical cooling rate of high-purity iron-carbon alloys ranging in carbon from 0.23 to 1.21%

The grain size established at temperatures from 1425° to 1600° F. increased markedly with decrease in rate of heating through the transformation range, whereas the grain size at 1800° F. was not so noticeably dependent upon the rate of heating. For any selected temperatures from 1600° to 2100° F. and with the heating rate employed, all the alloys were found to have approximately the same average grain size provided the carbon was completely dissolved at that temperature.

Carbon in solution, therefore, was not effective in inhibiting grain growth of the austenite in the high-purity iron-carbon alloys. The actual temperatures and the rate of heating through the transformation range were the dominant factors in controlling the austenitic grain size of these alloys. There is a narrow range in cooling rates in which the austenite transforms at Ar′ and a wide range in quenching rates in which the larger portion of the austenite transforms at Ar″. Thus, the transition from the unhardened to the hardened condition in high-purity iron-carbon alloys is brought about by a small change in cooling rate.

For complete solution and uniform distribution of carbon at the time of quenching, the critical cooling rate (R in °F. per sec.) or "hardenability" of the alloys may be approximately represented by the equation

$$R = \frac{410\, N^{0.4}}{C + 0.2}$$

where N is the number of austenitic grains per in.^{2} at 100 diameters and C is the carbon content in percent. The hardness values obtained on the quenched specimens could not alone be used as a precise index to the actual cooling rates of the alloys.
WAT (2a)

Welding "Chrome-Moly" Steel

"Weldability of Silicon-Chromium-Molybdenum Heat Resistant Steel." G. M. Tikhodeev & L. N. Solov'eva. *Metallurg,* Vol. 15, Feb. 1940, pp. 23-31. In Russian. Experimental.

Tests were conducted with the steel containing 0.15% C, 5-6 Cr, 1.5-1.7 Si and 0.3-0.5 Mo. The steel is used at 1300°-1400°F., but its welding is difficult because it has the property of air hardening. This results in a decrease of ductility with a resultant bad effect on the mechanical strength of the welded seams.

The best method of welding was found to be arc welding with electrodes of austenitic chromium-nickel steel of the 25 Cr-12 Ni or 25 Cr-20 Ni types. By tempering (after welding) at 1400°-1500°F. with air cooling, it is possible to eliminate the hardening effect and to raise the plastic properties of the welded seams. The heat treatment may be omitted in those cases where the welded members are to be used at high temperatures and where tempering in service may take place.

The resistance of the parent metal and of the welded seams to oxidation at 1300°F. in flue gases containing sulphur dioxide was equally high before and after welding.
BZK (2a)

2b. Non-Ferrous

Beryllium-Copper Alloys — Working, Treating, Finishing

"Beryllium-Copper Alloys." E. E. Halls. *Metal Treatment,* Vol. 6, Summer 1940, pp. 68-71, 78. Review.

Alloys of beryllium are available in the beryllium-copper, beryllium-nickel and beryllium-iron series, but the most important of these commercially are the beryllium-copper alloys. The beryllium-copper alloys respond to precipitation hardening, with a wide range of mechanical properties available through control of composition and of time and temperature of precipitation treatment.

The most widely-employed heat-treated alloys contain 2.0-2.5% Be. Solution annealing must avoid approaching too closely the melting point—1585° F.—and is usually performed at 1435°-1475° F. The time of treatment varies with furnace load and prior history of the material; 15-30 min. at temperature should suffice for cold-worked or ordinary wrought alloys.

The hot-working range is 1065°-1425° F. Like welding, working in this range causes the development of a duplex $\alpha + \beta$ structure, which may be homogenized by quenching from 1435°-1475° F. *after soaking for 2-3 hrs.* In the softened condition the beryllium-coppers are unstable and heating to any temperature up to about 1060° F. (for the 2-2.5% Be alloys) promotes transformation of α to $\alpha + \gamma$.

For the commercial alloys the advocated precipitation hardening range is 520°-700° F., with 575° F. usually employed; time at this temperature should be at least 4 hrs. Alloys containing about 2.30% Be have a tensile strength of 155,000 lbs./in.^{2} in the precipitation-hardened condition. When cold-work-hardened but not precipitation hardened, the tensile is 120,000 lbs./in.^{2} Superimposing precipitation hardening on cold-work-hardening results in a tensile strength of about 170,000 lbs./in.^{2} in commercial material. The compression, torsional and shearing strengths of work- and precipitation-hardened material surpass those of beryllium-copper in other conditions, but the impact strength is less.

Forming, drawing and machining present no special problems. Cold-worked-plus-precipitation-hardened alloys are easiest to machine. For blanking, a lubricant consisting of a 50/50 mixture of mineral oil (viscosity Redwood No. 1 at 70° F., 450 sec.) and paraffin oil is sufficient for all thicknesses below 1/32 in., and a machine oil above this. No verdigris troubles arise with this lubricant. For severe drawing, a compound of the chalk-loaded calcium soap type thinned with light mineral oil is satisfactory. For cutting, a good sulphurized cutting oil or soluble oil is employed.

Spot welding is practicable, but heavy currents and short time periods are essential; electronic control is advocated. For fusion welding, the carbon-arc process is usually employed, using a beryllium-copper

rod, without flux. The parts to be welded should be placed on a heavy steel block to induce rapid chilling; all welds should be hammered and the parts subsequently homogenized. For soft soldering, a fluoride flux should be used. Silver-soldered work must be homogenized, a requirement that limits the solder employed to one melting between 1475° and 1590° F.

Pickling is best done in sulphuric acid baths, and the "clean" but stained material should be subsequently given a dip in a bichromate solution consisting of 1 part sulphuric acid to 7 parts water, to which is added 2 oz. of sodium or potassium bichromate per gallon. Plating techniques follow orthodox procedures, light nickel plating being adequate for many purposes. Cadmium or zinc plating should not be applied for permanent finishing.

Beryllium-coppers containing from 0.25 to 0.50% Ni are said to be resistant to grain growth at the high solution-anneal temperatures usually employed. This is important since grain growth shows up in deep press work as roughening of the surface at corners. A complex alloy containing 1.4-2.0% Al and 1.0-2.0% Si with 1.4-1.7% Be has been used because it can be conveniently produced direct from the ore. Its mechanical properties are similar to ordinary 2% Be copper, but its conductivity is only 10% of electrolytic copper as compared with 35% for the straight beryllium-copper.

[This article does not mention the beryllium-coppers containing cobalt recently introduced in this country. One of their chief advantages over straight beryllium-copper is said to be the wide range of temperatures at which precipitation hardening can be performed without danger of over-heating and softening—material can be held up to 8 hrs. at 600° F. without resoftening. Tensile strengths of cold-worked-plus-precipitation-hardened material up to 200,000 lbs./in.² can be obtained, with elongation of 2-3%. The cobalt-containing beryllium-coppers have an electrical conductivity of about 30% that of electrolytic copper.—F.P.P.] (2b)

Cadmium Plating

A Composite

Cadmium plating has had to engage in a long uphill battle, chiefly economic, to attain its present important position in the finishing field. Always satisfactory technically, the quality has been improved steadily, but its application is still limited by the occasional cost rises as compared to zinc plating.

The general properties available, latest innovations, new uses and cost data for cadmium plating are reviewed by A. BREGMAN ("Cadmium Plating," *Iron Age*, Vol. 145, Apr. 15, 1940, pp. 36-40). Cadmium plating is used more for atmospheric corrosion protection than for decoration, and is slightly less effective than zinc in some environments. Although not generally resistant to chemicals, it has some advantages. Cadmium-plated surfaces can be readily soldered. Their low contact resistance makes them suitable for electrical contact surfaces.

Cadmium plating can be produced in thicknesses up to 0.03 in. Recently, Udylite Corp. produced coatings with high ductility in thicknesses ranging from 0.00085 in. to 0.0255 in. at 180° angle without cracking of coating. Although cadmium may be applied by spraying or even by hot dipping, it is mostly electrodeposited in still tanks or barrels.

A typical bath for still plating is as follows: 6.5 oz. sodium cyanide, 5.5 oz. cadmium cyanide, 2.7 oz. sodium hydroxide; an alternative bath is 4 oz. cadmium oxide, 1 oz. sodium cyanide. Current density may be 10-50 amps./ft.², voltage 2-2½. Arsenic, antimony, lead, silver and tin must be kept out of the solution to avoid dark, rough and spongy deposits.

Addition agents for brightening are: Gulac molasses, gelatin, dextrin, etc.; nickel in minute quantities may also be used. Addition agents also improve the hardness of deposits. According to Soderberg, the hardest plates are always found within the bright range of solution. Acid cadmium baths have been developed for producing "adhesive" plates for flash coatings prior to plating from cyanide baths. Good adhesion can thus be obtained on stainless steel and on certain aluminum alloys.

A large portion of commercial cadmium plating is done in barrels, using current densities and voltages of 175-500 amps./barrel and 7-12 volts. The solutions are usually held at 70°-95° F. by cooling coils. In barrel plating, the work must be dumped out before rinsing; rinsing the barrel increases drag out losses. In cost estimating, it can be figured that 1 lb. of cadmium will cover about 100 ft.² of surface with an average coating of 0.0002 in.

Automatic cadmium plating as applied by a manufacturer of radio tuning condensers is described by A. W. STEINBERGER ("Cadmium Plating with Automatic Equipment," *Products Finishing*, Vol. 4, June 1940, pp. 30-38). The work is delivered to the plating room in boxes, barrels, etc., from the press and is racked by operators on a monorail chain conveyor, which carries the parts to a tunnel type power washing machine. From here the conveyor carries the parts to the loading station of the plating machine where the racked work is transferred to the carrier cross bars of the plating unit.

The sequence of operations in this unit are as follows: Electric cleaner, warm water rinse, hot acid, cold rinse, electric cyanide, cadmium plate, water spray, bright dip, water spray, hot water rinse, automatic air blast and hot air drier. The entire cycle takes place in about 10 min., using a chain speed of 42 in. per min. Production capacity is about 3500 assemblies per hr. with an average deposit of 0.0002 in.

The cadmium tank is equipped with an agitator, which prevents stratification and mixes in new chemicals. A portable filter keeps the solutions free of sediment. The setup includes 3 d.c. generators. The use of a wetting agent in the sulphuric acid treatment greatly increases its activity and reduces fuming. X (2b)

Bright Zinc Plating

A Composite

The earlier method of producing bright zinc was to bright dip a pure zinc coating (plated from a cyanide bath) in certain oxidizing solutions, such as dilute nitric acid, acidulated hydrogen peroxide, or a chromic acid solution. The presence of lead, copper, tin, cadmium or arsenic in the zinc resulted in dark, streaky deposits after bright dipping.

These metals can be chemically or electrochemically removed from the bath before plating out the zinc. However, direct methods of producing bright zinc are obviously better, and two basic practices for doing this have recently been described.

According to CLARENCE W. SMITH of Philco Radio & Television Corp. ("Recent Developments in Bright Zinc Plating," *Mo. Rev. Am. Electroplaters' Soc.*, Vol. 27, Apr.

1940, pp. 255-261) the addition of 0.5 oz./gal. of sodium thiosulphate and 0.07 oz. /gal. of sodium sulphide to the cyanide zinc bath enabled bright deposits to be directly obtained at current densities of 35-40 amp./ft.^{2}, at room temperature. The addition of molybdic acid (MoO_3) and an organic brightener results in a further increase in brightness. A typical bath contains the following: 10 oz./gal. $Zn(CN)_2$; 8.5 oz./gal. NaCN; 10 oz./gal NaOH; 1.7 oz./gal. MoO_3; and 0.15 oz./gal. organic brightener. The above-mentioned quantities of sodium sulphide and thiosulphate may also be added. The current density should be above 30 amps./ft.^{2} and the temperature 95°-100° F.

As the zinc content of the bath tends to increase, it must be diluted occasionally and its composition adjusted accordingly. To develop the maximum brightness of coating, a bright dip must be used. The deposits contain 0.90-1.10% of molybdenum. Salt spray tests showed that the molybdenum did not materially affect the corrosion resistance of the coating.

R. O. HULL of du Pont ("Magnesium as a Control Agent for Zinc Anodes," *Proc. Am. Electroplaters' Soc.*, June 1940, Preprint, 3 pp.) points out that the accumulation of zinc in cyanide baths is caused by the lower value (85-95%) for the cathode current efficiency than for the anode current efficiency (97-105%). Since bright baths require close control, some method of equalizing electrode efficiencies should be applied. Neither mercury- or aluminum-containing anodes nor the use of insoluble (steel) anodes was very successful, for one reason or another. However, the addition of small quantities of magnesium or calcium to zinc anodes causes a noticeable decrease in anode current efficiency, and control of anode composition permits regulation of the bath.

Addition of 0.18% Mg reduces the anode efficiency of pure zinc from 100% to about 84%. If the zinc contains 0.1% Pb, the efficiency is reduced almost 50%. To produce the same effect, more than 1% Ca must be used. Both magnesium and calcium additions also result in the formation of insoluble compounds in the bath that carry down suspended matter. AB (2b)

Plating Zinc Die Castings

A Composite

The trend in electroplating practice for zinc alloy die castings is definitely toward automatic operation—a natural concomitant of the widespread and still-growing use of this metal-form. Similarities and differences in present practice in different shops can be noted in three recently-published articles.

The plating procedures in 3 large plants are described by W. W. BROUGHTON of Morris P. Kirk & Sons, Inc. ("Modern Practice in Plating Zinc Alloy Die Castings," *Mo. Rev. Am. Electroplaters' Soc.*, Vol. 27, May 1940, pp. 339-345). Bright copper plating tended to give rough deposits and the Rochelle salt bath was used instead. Bright nickel plating was used in all three plants. The plating procedures deviated but little from standard practice. Electro-cleaning was omitted in some cases and an alkaline soak or a power washing machine was used instead.

The effect of various cleaning procedures on the adherence of copper-nickel composite coatings on zinc die castings is discussed by B. F. LEWIS of Northwest Chemical Co. ("The Relationship of Cleaning Technique and Adhesion of Electrodeposits," *Proc. Am. Electroplaters' Soc.*, June 1940, Preprint, 7 pp.). Cleaning and plating procedures that exposed the die casting to a minimum of hydrogen evolution resulted in a slower rate of diffusion of copper into the casting at elevated temperatures and in better adhesion. Adhesion was improved also by preparatory treatments that caused the copper to follow the crystal orientation of the base metal.

The practice of Alemite Die Casting & Mfg. Co. in plating large quantities of automotive zinc alloy die castings is described by HERBERT CHASE ("Automatic Plating of Die Castings," *Iron Age*, Vol. 145, June 27, 1940, pp. 40-41). Castings are buffed (as a rule no grinding or polishing, except at die partings, is required) before being placed on a machine that automatically carries them through the cleaning, copper-plating and nickel-plating stages.

High-pressure spray cleaning, with a hot, mild alkaline cleaner, is employed. Copper-plating, also automatic, is applied from a cyanide bath giving a 0.0003 in. (minimum) coating, and bright enough to form a good base for the bright nickel, which follows. The latter coatings (applied by the McGean method, with organic carrier and brightener) are so bright that buffing before chromium plating (or before shipment if chromium-plating is omitted) is seldom required.

Chromium-plating is not automatic, but is efficiently carried out with a simple, inexpensive handling method comprising 2 overhead electrically operated cranes each carrying an electric hoist with controls at convenient height. Two operators can handle per hour about 30 carriers, each holding several racks of castings. X (2b)

Properties and Applications 3

METALS, ALLOYS, METAL FORMS ENGINEERING DESIGN, METAL SELECTION

Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

3a. Ferrous

"Pearlitic Malleable" Castings

"Properties of Commercial Pearlitic Malleable Iron." C. H. Lorig (Battelle Mem. Inst.) *Am. Soc. Testing Materials,* Preprint No. 38, June 1940, 6 pp. Survey.

The mechanical properties of the various commercial (usually proprietary) pearlitic malleables on the American market are correlated, and data are summarized in a comprehensive table. The term "pearlitic" as here used is generic and embraces not only malleable irons in which the matrices contain pearlite, but also irons containing a certain amount of combined carbon in any form (for example, Z-Metal, which is characterized by spheroidized carbide in the matrix).

Because the pearlitic malleables contain combined carbon in the matrix, whereas standard malleables do not, the former are stronger, harder and less ductile than ordinary malleable. Pearlitic malleables are made from white cast irons (usually of standard malleable analysis) by either (1) cutting graphitization short during the second stage of heat treatment, thus leaving some of the carbon combined, or (2) completing the graphitization and subsequently heating into the critical range to recombine some of the carbon, or (3) incorporating alloying elements so as to require no modification of the regular anneal.

Assembling all data available for about 16 commercial pearlitic malleables revealed that tensile strength and yield point values varied in direct proportion to hardness changes, between 120 and 260 Brinell. In other words, the various processes for producing these irons give substantially the same tensile strength and the same yield point for a given Brinell hardness, for any one composition. Ductility, however, is sensitive to the character of the combined carbon, hence variations in elongation among the variously-processed irons are realized irrespective of the hardness or strength values.

Different types of pearlitic malleables can thus be produced with properties that vary from those of standard malleable [50,000 lbs./in.^{2} tensile, 10-18%, elongation] to those with a tensile strength of 125,000 lbs./in.^{2} and elongation of 2-3%. A matrix in which the combined carbon is spheroidized is, generally speaking, more ductile than a sorbitic matrix, which in turn is more ductile than a coarsely lamellar-pearlitic matrix—all for irons of about the same tensile strength and combined carbon contents.

Individual pearlitic malleables are reported to be superior to other ferrous metals with respect to certain properties taken singly. Thus, Z-Metal has double the notch-impact value of standard malleable; ArMaSteel was 20-40% more machinable than steel bar stock and drop forgings of the same hardness. These data should not be generalized to apply to all pearlitic malleables, however.

Z-Metal, Gunite K, Mallix, ArMaSteel, Promal, Belmalloy, Belectromal, Perduro, Super Y, Meehanite Malleable, and Jewell Alloy are some of the pearlitic malleables discussed and compared. (3a)

Corrosion Inhibitors in Air Conditioning Systems

"Tests of Corrosion Inhibitors for Water Treatment in Air-Conditioning Equipment." James H. Wilson & Edward C. Groesbeck. *J. Res. Natl. Bur. Standards,* Vol. 24, June 1940, pp. 665-676. Research.

Treatment of the circulating water used in air-conditioning equipment with small amounts of certain chemicals and control of the pH of this water greatly reduce the losses resulting from corrosion. The order of efficiency of the inhibitors studied was (a) chromates (the best), (b) silicates, (c) phosphates, and (d) carbonates.

The differences in the corrosion resistance of the various kinds of iron and steel used were slight in comparison with the effect of a change of inhibitor or of condition of test. All of the inhibitors tested, with the exception of 100 p.p.m. of sodium carbonate, decreased the rusting of iron or steel. The studies involving the sodium silicates indicated that the higher the ratio of silica (SiO_2) to soda (Na_2O), the greater was the inhibiting action.

The *distribution* of corrosion, especially in the spray, was more uniform in the presence of an inhibitor than it was in its absence. In the case of all the inhibitors used, corrosion to some extent occurred in crevices but it failed to occur on flat, uniformly exposed, metal surfaces in 2 instances. However, with inefficient inhibitors, the rusting was less in the crevices than on the fully exposed surface. In this case, the amount of corrosion appeared to be a function of the available space within the crevice.

WAT (3a)

High Speed Steel Forgings vs. Bar Stock

"Practical Notes on High Speed Steel Forgings." W. H. Wills (Allegheny Ludlum Steel Corp.) *Trans. Am. Soc. Metals,* Vol. 28, June 1940, pp. 424-439; discussion, pp. 440-444. Review plus research.

"Many times in our shop we have listened to old-time mechanics insist that no tool such as chisels, scrapers, punches, tool bits, etc. is any good unless it has been heated up and hammered a little" says one of the discussors (W. E. Bancroft of Pratt & Whitney Div.) of this paper, in evident agreement with the author's conclusion that in the middle-sizes of 18-4-1 high speed tools, forgings offer advantages over bar stock.

High speed steel is furnished in the form of hot-rolled or hammered annealed bar stock, cold-finished bars, and forgings. Bar stock generally includes sizes from 1/4 in. to 8 in. round or equivalent. Sizes up to 4.5 in. round are generally rolled, and above this, hammered. As the size increases, the problem of uniformity of carbide distribution becomes more difficult.

The use of forgings in place of the larger sizes of bar stock is now quite general among the cutting tool manufacturers, although much depends on the type of tool and the length or thickness with respect to the diameter. The advantage of forgings over large bar stock lies in the more homogenous structure of the former, resulting in finished tools of greater strength and cutting quality.

The mill's problem in obtaining satisfactory carbide distribution throughout the wide range of bar stock sizes is considerable. Long heating cycles and structural considerations limit ingot sizes to larger figures, and larger tool sections thus get relatively less working from ingot to finished bar than do soft steels. Also, the penetrating effect of the hammer is less than with soft steels, hence large sizes of bar stock may have a center structure with cellular distribution of the carbides.

In upset forgings, on the other hand, the metal is worked transversely as well as longitudinally, resulting in more uniform carbide distribution. Also, by starting from a relatively small billet from a smaller ingot than would be used for equivalent bar stock, the primary carbide particles are smaller. On the other hand, the production of high speed steel forgings is not immune from quality hazards, several of which are discussed.

There is some difference of opinion as to the limiting size for bar stock. A shift to forgings brings little structural improvement for sizes under 3 in., but as the diameter increases to 4 in. the advantages in forgings become more pronounced. This continues as the diameter increases and the thickness is less than 50% of the diameter. For sizes of 7 in. and over, and with lengths over 50% of the diameter, any advantage over bar stock is doubtful. These statements are based on a study of microspecimens. Impact tests (unnotched Izod) also gave better results for forgings than for bar stock.

Although the value of the impact tests was minimized in the discussion, all discussors agreed that practical experience generally demonstrated forgings to be superior to bar stock for high speed steel milling

Notes on National Defense

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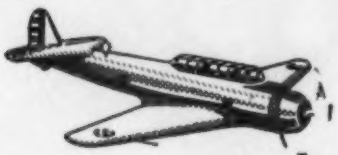

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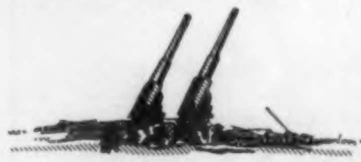

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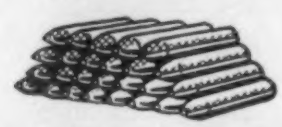

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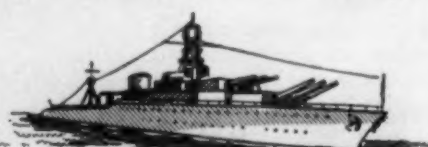

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cutters, hobs and other tools in the sizes indicated. One discussor claimed that forgings finished in "shape dies" were much superior to those finished in "flat dies."

FPP (3a)

Irons and Steels at High Temperatures

A Composite

High temperature service problems are the concern of metallurgical engineers in all the metal-producing and metal-using industries. In steel plants, non-ferrous mills, and foundries, as well as in industrial heat treating shops, furnaces must be equipped with parts that will resist scaling and be mechanically serviceable at temperatures up to 2000° F. and beyond. And there is scarcely a metal-consuming industry whose engineers don't have to scratch around, in designing their products, for materials to resist the effects of heat in service—in oil refining, in the process industries generally, in electrical power equipment, in steam power, railroad and marine equipment, in industrial plant and domestic heating systems, in service-heated parts of engines and machines, etc., etc.

Among the phases of this general subject covered in recent articles are plain and alloy cast irons for elevated temperatures, highly-alloyed heat resistant materials, structural behavior of austenitic steels at high temperatures, and creep problems with alloy steel bolting materials.

Cast Irons

Among the cast irons, the simplest group that has any significant heat resisting value are the high strength irons, according to R. C. TUCKER ("Chromium Heat Resisting Cast Irons," *Foundry Trade J.*, Vol. 62, June 20, 1940, pp. 463-464, 471; June 27, 1940, pp. 485-486, 490). Their more stable pearlite and finer graphite than ordinary iron confer superior growth resistance at 850°-1000° F. Unalloyed high-strength irons do not resist scaling nor heat-shock and on short-time tensile tests their strength is satisfactory only up to 930° F.

Low alloy irons are likewise not resistant to heat shock, and are only slightly more scale-resistant than high-strength irons. They depend for their high temperature strength on close control of structure and analysis. The best method of adding chromium seems to be in the ladle, using a modern exothermic addition agent—for example, "Chrom X," a mixture of chrome ore with carbonaceous material and thermit that glows white hot and dissolves completely in the metal when added to it. (See also the "Trend" on this subject in our June issue, page MA 372). Service reports show satisfactory performance at 1750° F. of 9-ton retorts made of cast iron containing 3.25% total C, 1.2 Si, 0.6 Mn, 0.1 S, 0.1 P and 0.65 Cr.

Discontinuities in the strength/temperature curve of low-alloy irons containing silicon, nickel or chromium were examined by F. ROLL ("Beitrag zur Zugfestigkeit von Gusseisen in Abhangigkeit von der Temperatur," *Giesserei*, Vol. 27, Apr. 5, 1940, pp. 123-124). For example, one pearlitic iron had a tensile strength of 37,000 lbs./in.^{2}, at 70° F.; this dropped to 13,500 at 1250° F., rose to 15,300 at 1275° F., dropped to 13,000 at 1300° F., and then gradually dropped off to 2,000 at 1650° F. Discontinuities of this type occur in plain cast irons, but are most prominent in alloy irons, and seem to take place in the A_1-A_3 transformation range. From an engineering standpoint this temporary increase in strength is of no practical importance.

Tucker also discusses high-alloy irons, such as Nicrosilal and Ni-Resist, which are scale-resistant up to 1800° F. and have appreciable bending strength at 1550° F. Aluminum as a constituent of cast iron considerably improves its scale resistance, but the difficulty of getting the aluminum in the iron was almost insuperable until a special technique was developed to produce an iron known as "Cralfer" containing 7.5% Al and some chromium (see "Cast Iron for Modern Engineering Applications," T. TYRIE, *Foundry Trade J.*, Vol. 62, Mar. 7, 1940, pp. 185-187).

High Chromium Alloys

Values for the "scaling index" (gain in weight in mg./cm.^{2} for 7 cycles of heating and cooling in burnt city gas) and "time-yield" stress (giving an average creep of 10^{-6} in./in./hr. between 24 and 72 hrs. at 1300° F.) are tabulated for a series of plain chromium steels and industrial heat-resistant alloys by W. H. HATFIELD ("Heat Resisting Alloys," *J. Birmingham Met. Soc.*, Vol. 19, Dec. 1939, pp. 155-168). Some typical values are given in the accompanying table.

Alloy	Scaling Index at 1800° F.	Time-Yield Stress at 1300° F., lbs./in.^{2}	Max. Temp. of Use °F.
13 Cr stainless	250	240	1400
18/8 with Ti	175	4480	1475
8 Cr, 4 Si	0.64	300	1650
14 Ni, 13 Cr, 3 W	110	3360	1850
19 Cr, 7 Ni, 4 W	2.8	3920	2000
25 Cr, 21 Ni	5.1	3360	2100
33 Cr	2.3	320	2100
78.5 Ni, 13.5 Cr (Inconel)	...	3920	2100

Sometimes it is found that certain austenitic nickel-chromium-iron alloys show, before being placed in high temperature service, an abnormally large grain size in localized areas, which leads to local weakness and early failure in use. The probable cause of this was sought by A. PORTEVIN & R. CASTRO ("Etude de la Recristallization d'ure Austenite Speciale au Nickel-Chrome," *Bull. Assoc. Tech. Fonderie*, Mar./Apr. 1940, pp. 47-50) by variously cold working and annealing specimens and noting their recrystallization behavior.

The abnormal results were obtained when the specimens were overheated in the range 2000°-2200° F. Apart from this, there were no unusual recrystallization phenomena, *e.g.* transformations, etc. The structural changes produced by a small amount of cold work may result, in heating, in the very large grain size.

Alloy Steel Bolting Materials

Materials selection, relaxation and creep testing, and service requirements of alloy steels for bolting are discussed by J. J. KANTER of Crane Co. ("Reducing Creep in Alloy Steel Bolting Materials," *Steel*, Vol. 106, Mar. 4, 1940, pp. 44-48, 72). Relaxation tests of actual bolted joints at elevated temperature indicate that bolting relaxation may be the determining factor in maintaining tight joints when service temperatures are very high. There is no real basis in the A.S.T.M. alloy steel bolting materials specification (A 193-39T) for accepting as relaxation and creep-resistant any of the 11 steels there listed. A short-time acceptance test (supplementing the required tension tests) for bolting materials still needs to be developed.

Only one steel (B14) in the specification calls specifically for a normalizing treatment followed by a draw. It was developed by the author's company and is called "Templex." It contains 0.35-0.50% C, 0.40-0.70 Mn, 0.04 max. P, 0.05 max. S, 0.15-0.30 Si, 0.80-1.10 Cr, 0.30-0.40 Mo and 0.20-0.30 V. This steel is unusual in that it comes through a normalized-and-draw treatment with excellent tensile properties.

As oil quenched and drawn, B14 has high temperature short-time tensile properties similar to those of B7 (S.A.E. 4140) steel. However, at 900° F., the properties of oil-quenched B7 and *normalized* B14 respectively are: (a) tensile strength, lbs./in.^{2}, 98,000 and 116,000; (b) yield point, lbs./in.^{2} 73,000 and 88,000; (c) creep stress, 1% per 10,000 hrs., lbs./in.^{2}, 20,500 and 59,000; and (d) creep stress, 0.1% per 10,000 hrs., lbs./in.^{2}, 10,000 and 40,000.

Relaxation tests showed a decline from 30,000 lbs./in.^{2} to 25,300 lbs./in.^{2} for normalized B14 after 180 days at 850° F. This indicates that a number of years would be required for relaxation to 15,000 lbs./in.^{2}, the approximate stress at which leakage occurs in the usual high-pressure flanged joint. At 850° F., B7 relaxed to the 15,000 lbs./in.^{2} leakage point in but 63 days.

Studies of relationship of creep resistance to microstructure tend to show that an optimum grain-size range exists in which an alloy steel is most resistant to creep. For B14, this range seems to be about A.S.T.M. No. 5-7. Finer grain size represents too great a proportion of the material in the "disorganized" condition which promotes creep, while larger grain size does not afford enough "keying" against plastic deformation.

X (3a)

Ferrous Alloys to Resist Hydrogen Sulphide

THE EFFECT OF GASES CONTAINING HYDROGEN SULPHIDE ON IRON AND SOME IRON ALLOYS ("Ueber den Einfluss schwefelwasserstoffhaltiger Gase auf Eisen und auf einige Eisenlegierungen") W. BAUKLOH & E. SPETZLER. *Korrosion u. Metallschutz*, Vol. 16, Apr. 1940, pp. 116-121. Research.

In the various processes for hydrogenating coal, hydrogen sulphide is formed and presents a formidable corrosion problem. Materials that might be suitable for the equipment used in this process were investigated. The attacking gases were mixtures of nitrogen with hydrogen sulphide and of hydrogen with hydrogen sulphide; ingot iron and manganese, chromium and aluminum steels were exposed to the gases.

Alloys of iron with aluminum and chromium proved particularly corrosion-resistant. Corrosion by hydrogen - hydrogen sulphide mixture was less at higher temperatures than corrosion by nitrogen - hydrogen sulphide mixtures, while at low temperatures the conditions are reversed. Alloying iron with carbon increases the corrosion resistance but does not give a corrosion-proof material; the resistance of a 0.45% C steel to hydrogen sulphide gases was about 30% higher than ingot iron. Silicon improves but slightly the resistance to attack by hydrogen sulphide gases.

The addition of 1.5% Ni gave a slight improvement for temperatures up to 950° F., although above 1300° F. such nickel steels were no better than ingot iron, probably because of the relatively low melting point of the nickel sulphide corrosion product. In general, the protective effect of an alloying element is determined chiefly by the physical properties of the solid corrosion products formed. This accounts for the good protection afforded by the aluminum content of some steels. On the aluminum steels, two layers of scale could be observed

at 950° F.—an easily removed outer film and a well-bonded inner layer. At 1300° F., 3 layers are formed—the outermost smooth and silvery, the intermediate layer soft and pliable, and the innermost, mainly alumina (Al_2O_3), firmly bonded and highly protective. Ha (3a)

Pitting and Fatigue of Steels

"INFLUENCE OF CYCLIC STRESS ON CORROSION PITTING OF STEELS IN FRESH WATER, AND INFLUENCE OF STRESS CORROSION ON FATIGUE LIMIT." DUNLAP J. MCADAM, JR. & GLENN W. GEIL. *J. Res. Natl. Bur. Standards*, Vol. 24, June 1940, pp. 685-723. Research.

By examination of surfaces and longitudinal sections of specimens of steel after stress corrosion, information has been obtained on the influence of cyclic stress (during corrosion) on the form and size of corrosion pits. A discussion is given of the theoretical stress concentration due to corrosion pits, and of the influence of size on the effective stress concentration. By comparison of typical views of corrosion pits with curves representing the decrease of the fatigue limit with corrosion time, the forms and sizes of corrosion pits are correlated with the resultant lowering of the fatigue limit.

The stress corrosion process is discussed in terms of the general theory of corrosion of metals. With increase in cyclic stress and cycle frequency, the corrosion process is shifted from a cathodically controlled process toward an anodically controlled process. The results of examination of specimens corroded with and without cyclic stress indicate that cyclic stress tends to increase the size of corrosion pits, to cause transverse extension and merging, and to cause increase in relative depth.

When the combined influence of stress, cycle frequency, and corrosion time is sufficiently great, transverse fissures appear at the equators of the rounded corrosion pits. When the combined influence of these three variables is somewhat less, transverse crevices are formed. When the combined influence is still less, the rounded pits may merely extend laterally and deepen, without loss of rounded contour. When the combined influence is small, the chief effect may be an increase in the size and relative depth of the rounded pits.

Cyclic stress, while increasing the size of the pits, apparently decreases the tendency of pits to spread and form shallow saucers. Cyclic stress may have great effect on the size of a few pits, while having little apparent effect on the size of most of the pits. The range of both form and size of the corrosion pits on any one specimen may thus be greatly increased. Cyclic stress may accelerate corrosion, not only by increasing the permeability of the film and layer of corrosion products, but also by increasing the solution pressure of the metal.

The relative importance of these two factors probably varies with the kind of metal, the intensity of the general corrosion, the properties of the corrosion products, the cycle frequency, and the stress. Under moderate or severe general corrosion, the important factor is the influence of cyclic stress (in the metal) on the permeability of the coating. Under slight general corrosion, and especially under relatively high stress, an important factor may be the influence of stress on the solution pressure of the metal.

The lowering of the fatigue limit must be attributed to stress concentration around corrosion pits. Because of stress concentration, the actual stress around a pit may be above the fatigue limit, when the nominal stress (estimated from the applied load and the dimensions of the specimen) is much less. Stress concentration, therefore, must be considered in any attempt to correlate the forms and sizes of corrosion pits with the lowering of the fatigue limit. WAT (3a)

3b. Non-Ferrous

Nickel-Bronze Castings—A General Utility Alloy

"A GENERAL UTILITY NON-FERROUS CASTING ALLOY." A. DUNLOP. *Foundry Trade J.*, Vol. 62, May 30, 1940, pp. 397-399. Descriptive survey.

To reduce the number of casting alloys, utilization of heat treatable alloys seems promising. Such alloys can by treatment be made to several physical specifications without changes in composition or foundry practice.

The alloys of copper, nickel and tin have been previously shown by others to have promise in this direction. The author reports on the properties of an 88% Cu, 5 Sn, 5 Ni and 2 Zn alloy, and compared them with those of Admiralty gunmetal, phosphor bronze and high tensile brass.

The Brinell hardness of the 88-5-5-2 alloy can be varied between 80 and 200 by suitably adjusting the heat treatment. For the best properties, a double heat treatment should be employed. The first stage consists in heating at a high temperature; followed by rapid cooling, such a treatment produces maximum softness. The second stage involves reheating or aging at a much lower temperature. Of the two sections of the heat treatment, the second is the more critical, since varying the time and temperature at this stage results in a wide variation in mechanical properties.

While the alloy responds very well to heat treatment, it nevertheless has excellent mechanical properties in the "as-cast" condition. From the tables given in the paper, it is evident that 88-5-5-2 nickel bronze is superior to the 88% Cu, 10 Sn, 2 Zn gunmetal, the superiority of the Izod impact value being most marked.

The yield point and the limit of proportionality of the heat-treated nickel-bronze are superior to those values for the phosphor-bronze and the high-tensile brass. The Izod impact value of 36 ft.-lbs. obtained in the nickel bronze aged at 475° F. is considerably higher than even the high-tensile brass (23 ft.-lbs.). When aged at 575° F., the nickel-bronze possesses a nice balance of properties, with Izod value equal to that of the high-tensile brass and proportional limit 2½ times greater and yield point 1½ times greater than the latter alloy.

A cylindrical sleeve nickel-bronze casting 3 in. long by 3⅜ in. external diam. and 2⅜ in. internal diam. in the "as-cast" condition successfully withstood an internal water pressure of 1450 lbs./in.^{2}, the maximum pressure capable of being produced by the testing apparatus. Even after the casting was machined internally to reduce the wall thickness to ½ in., the casting was still pressure-tight at 1450 lbs./in.^{2}

Thereupon the casting was heat treated for 5 hrs. at 1400° F., water-quenched, and aged 5 hrs. at 660° F. Retesting of the heat-treated casting showed it still to be pressure-tight at 1450 lbs./in.^{2} The section of the casting was then reduced to 5/16 in. by machining internally and externally, but again this reduction of section did not in any way affect the pressure-tightness.

The alloy might have useful qualities as a bearing material, although definite conclusions cannot yet be drawn. In the as-cast condition, the nickel-bronze requires a compression load greater than 15,500 lbs./in.^{2} to produce permanent deformation, and when heat-treated this value becomes 60,000 lbs./in.^{2} The figure for Admiralty gunmetal is 11,000, for phosphor bronze 13,500, and for high-tensile brass 18,000 lbs./in.^{2} The alloy has given successful performance in centrifugal water pump bearings and in the main bearing of an air compressor in the author's laboratory.

Admiralty gunmetal and phosphor-bronze are well known for their corrosion resistance to both fresh and sea water. The nickel-bronze compares favorably with these alloys in these media, the order of corrosion being about the same for all. AIK (3b)

Metal-Sprayed Bearings

"METAL SPRAYED BEARINGS FOR HIGH SPEED OPERATION." H. SHAW. *Pamphlet, Assn. Metal Sprayers* (Barclay's Bank Chambers, Dudley, England) Mar. 1940, 12 pp.

Bearing linings of several types applied by the metal-spray process are discussed, and friction and seizure-load test data given. Laboratory tests were made by pressing a flat metal-sprayed specimen, simulating the bearing, against a flat rotating disc, simulating the shaft. A dynamometer device measured the friction, and heated oil was supplied.

In the friction tests reported the metal-sprayed surface was compared with the same material in the cast state, when casting was possible. The hardness and initial finish of the steel disc is not stated, nor is it stated whether the samples were initially worn-in under light load before starting the friction test.

Operating under conditions that are probably comparable, though not stated, the sprayed surfaces were found to have lower friction and higher seizure loads than the cast material, this holding for tin-base babbitt (of which several sprayable compositions are mentioned but the one actually used is not stated), for so called "cadmium-silver-copper" (the listed analysis of which, however, is about 99% Cd, 0.5 Cu, 0.5 Ni with only 0.015 Ag), and for lead bronze, 80% Cu, 5 Sn, 15 Pb.

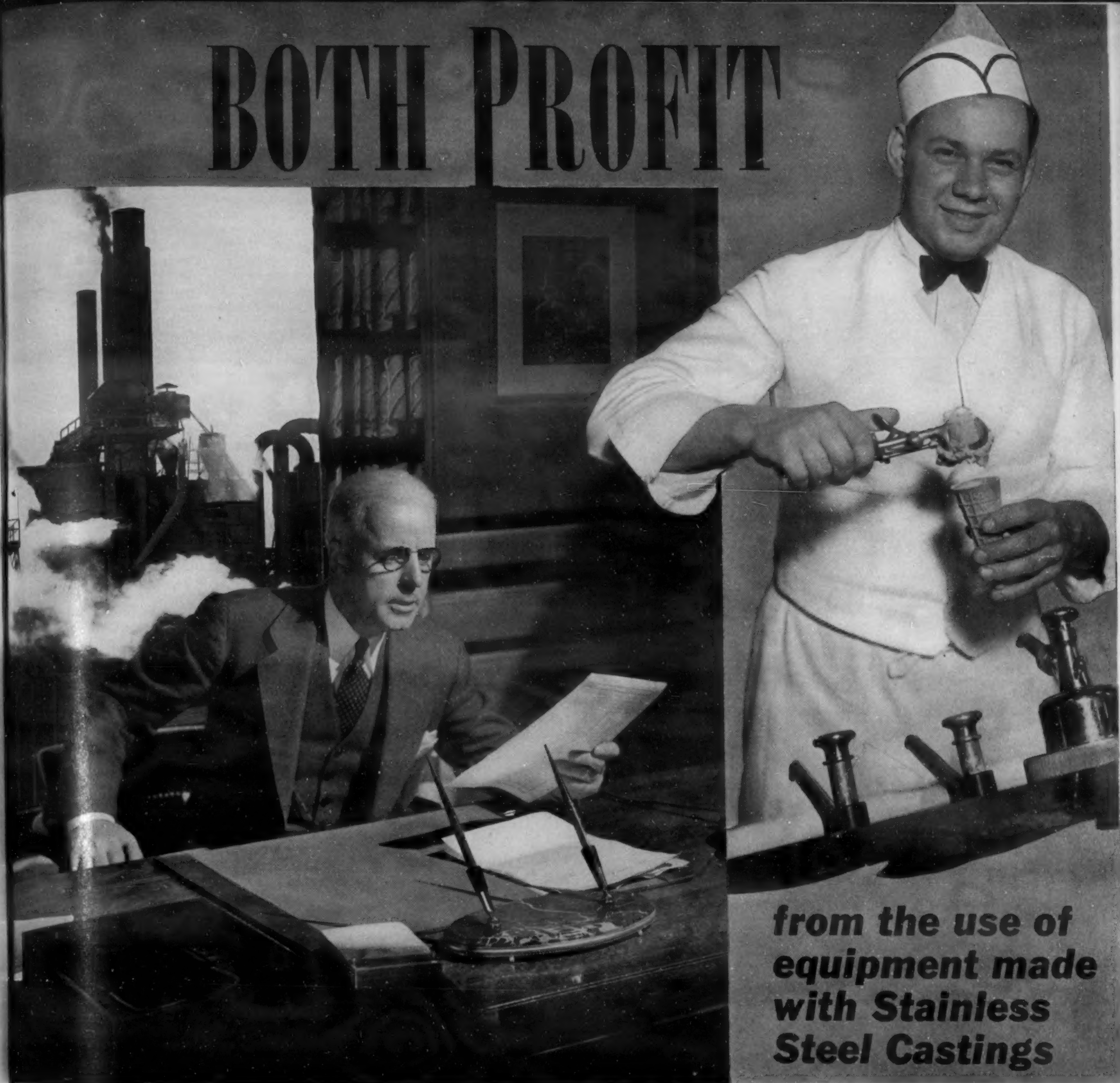
The sprayed lead bronze was better than in the cast condition when the sprayed surface was fresh, but, after running, it approached the same behavior as that of the cast material. The lead bronze was the poorest material tried, considering both coefficient of friction and seizure load. Sprayed tin-base babbitt had the lowest coefficient while the cadmium base had the highest seizure load, on the average of tests at 50, 1000, and 3000 ft./min.

Still lower friction and higher seizure load were shown by a copper backing "covered with fine pores or pits of a size such as say 0.005 in. deep by 0.003 in. diam., into which tin or tin-base metal is loaded by any convenient means. The tin-base metal cannot crack because it is held in the very fine pores or pits of the backing metal (copper, for example). In running, the load is taken by the tin-base metal so that the friction is that of a tin-base metal aided by the peculiar channel effect created between the tin-filled pores and the copper backing, the tin remaining in relief above the backing."

This material is thus an approach to a copper-lead type of bearing, with tin substituted for lead, and produced in such fashion that the tin pools are not hardened by diffusion of the copper, as would occur in hot-tinning.

No information is given on the load-carrying ability of any of the sprayed coatings in respect to resistance to deformation, and no comment is made as to whether they squashed out at the loads tabulated as being borne without seizure. The sprayed coatings are porous, and retain and exude oil in much the same fashion as a powder metallurgy bearing.

BOTH PROFIT



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Lebanon STAINLESS AND SPECIAL ALLOY **Steel Castings**

Shaw states that work is being carried on by others in England on sprayed aluminum-base alloys with "quite good" results. The final composition has not been selected. He indicates that an element producing a hard constituent such as copper, nickel, antimony or iron, with perhaps a little zinc for strength, and with tin and lead for anti-friction properties, may all be added to the aluminum. HWG(3b)

Zirconium

A Composite

Our present knowledge of and experience with zirconium metal are usefully reviewed in two articles in a recent issue of *Foote Prints*. In one, the production, properties and uses of ductile zirconium (and titanium) are described, and in the other the use of zirconium as a "getter" material is discussed.

The first step in the production of ductile zirconium and titanium, according to H. W. Gillett of Battelle Mem. Inst. ("Some Features of Ductile Zirconium and Titanium," *Foote Prints,* Vol. 13, June 1940, pp. 1-11) is the reduction of a zirconium salt with calcium or other strong metallic reducing agent to form a non-ductile metal in powder form. Attempts to agglomerate into a massive form that can be made ductile in the cold have not been very successful.

Zirconium oxidizes rapidly and absorbs hydrogen with increasing avidity from about 950° to 1550°F., gives some of it up as it passes through the inversion, and then takes up more on further heating. Titanium once charged with hydrogen will not give it all up by any purely thermal treatment. Oxygen and nitrogen are taken up above red heat and the oxides and nitrides are not only very stable but form solid solutions with the metals to an unprecedented degree. These properties greatly complicate hot working.

The production of massive metal, ductile in the cold, must therefore be carried out by vapor phase decomposition of zirconium or titanium tetra-iodide, the metal being deposited in crystalline form on an electrically heated hair pin filament into rods of about 1/4 in. diam. Since these crystals are formed above the inversion point, they retain the exterior appearance of the high temperature (beta, body-centered cubic) form on cooling, but below about 1580° F. the structure is alpha, hexagonal, so that the crystals of the rods are pseudomorphic.

Physical Properties

Although pure zirconium and titanium transform at about the same temperature (not far from 1580° F.) it takes an extraordinarily good vacuum to avoid contamination of the metal above 1475° F. with traces of oxygen or nitrogen. The inversion point is greatly reduced by such contamination. Contamination also increases electrical resistivity, and hardens and embrittles the metal. Even so, the crystal rods can be hot worked at around 925° F. with impunity and massive metal can be handled in air as long as it is kept below red heat.

It is customary to swage the bars of big crystal before drawing or rolling. If done at 750°-925° F., a surface film of oxide is formed that prevents adhesion of the metal to drawing dies and rolls.

The metals show a low rate of work hardening and will stand very large cold reduction to extremely fine wire and thin foil. The highest strength in fully cold-drawn wire was 142,000 lbs./in.^{2} tensile, 1% elongation; vacuum annealing for 3 hrs. at 750° F. gave 100,000 lbs./in.^{2} tensile, 3% elongation, while 3 hrs. at 925° F. gave 56,000 lbs./in.^{2} tensile and 12% elongation. Maximum Erichsen test on sheet was obtained after 30 min. at 980° F. or 2 sec. in a gas at 1300° F. (Annealing temperature for titanium is given as about 925° F.)

Electric pressure welding under control made possible by modern equipment makes fabrication of the metals by welding entirely practical. Zirconium under most conditions is more resistant to corrosion than titanium. Except for hydrofluoric acid and for very concentrated hot sulphuric and phosphoric acids, the acid resistance of zirconium is extremely good. Its resistance to alkali is also noteworthy, zirconium being superior to tantalum in this respect.

Preliminary appraisal of the dropwise characteristics of zirconium was obtained by making several experiments in which the metallic surfaces were exposed to different types of vapor. Zirconium exhibits the power of promoting dropwise condensation, which has already been recognized as a valuable property of tantalum, particularly with respect to heat-exchange applications.

Zirconium as a Getter

The properties of zirconium that make it a likely choice for "getter" materials in vacuum technique are recounted by J. D. Fast ("Zirconium as a Getter", *Ibid.*, pp. 22-30). "Getters" are metals employed in high vacuum work for the purpose of binding gases chemically and thus shortening the pumping time; magnesium has


CAST
STEEL
GEARS

been used extensively as a getter. After evacuating vacuum tubes to a certain low pressure, the getter metal is volatilized; in the gaseous state, it removes the gases more rapidly and produces a lower final pressure than is possible by means of high vacuum pumps alone.

Of more recent interest are metals that in vapor or solid state not only shorten the pumping time, but which in the solid state are able to fix the gases released after the tube has been sealed off the pump *(i.e.* during its useful life). Under certain conditions, zirconium satisfies this requirement.

In contradistinction to *corrosion resistant* metals, which are usually those that assume a good protective oxide film, *getters* are generally metals that take a poor protective oxide film. Among the relatively corrosion resistant metals are also those (aluminum, chromium, titanium, zirconium and tantalum) that have high heats of formation of the oxides, leading one to expect high corrodibility by oxygen.

From consideration of the nature of oxide film formation and the heat of formation of oxide, it follows that a good getter must not only satisfy the requirement of a great affinity with oxygen, nitrogen, hydrogen and carbon, but during reaction no dense, compact layers shall be formed to delay further action.

In the case of the alkali (lithium, sodium, etc.) and alkaline earth metals (magnesium, calcium, etc.) the volume of the oxide is smaller than that of the metal, leaving base metal exposed to further attack. Of the alkali metals, none has a melting point too low or vapor pressures (except lithium) too high to prevent their use as getters. The alkaline earth metals are often used as getters, their chemical activity increasing in the order magnesium, calcium, strontium, barium, with magnesium functioning only during the process of evaporation, while barium also absorbs gas in the solid state.

In the case of titanium and zirconium, no sealing layers are formed at high temperatures, because the solubility of oxygen and nitrogen in these metals is very high. At the same time, there is the advantage that at low temperatures very good protective layers are formed, making these metals stable in air. Large quantities of hydrogen can also be absorbed by zirconium in solid solution.

The table below lists some of the physical properties of zirconium [taken from both articles]:

Modulus of elasticity (wires of 0.01 in. diam.)	10,700,000
Melting point, °F.	3,360
Electrical resistivity, ohm-cm.	0.41×10^{-4}
Coefficient of thermal expansion/deg. F. at room temperature	3.3×10^{-6}
at 900° F. (500° C.)	4.5×10^{-6}
Specific gravity	6.52
Atomic number	40
Atomic weight	91.22
Crystal structure at low temperature	hexagonal close-packed
Crystal structure at high temperature	body-centered cubic
Transition point hexagonal to Zr cubic Zr	865° C.
Coefficient of spectral emissivity of the cubic zirconium red (= 6550 A. U.)	0.43
Thermionic work function of cubic zirconium, in electron-volts	4.13

RAW (3b)

Fatigue of Brass

"BEHAVIOR OF CRYSTALLINE STRUCTURE OF BRASS UNDER SLOW AND RAPID CYCLIC STRESSES." R. A. WOOD & P. L. THORNE (Nat'l Phys. Lab.) *Proc. Roy. Soc.* [*A*], Vol. 174, Feb. 1940, pp. 310-321. Original research.

Definite evidence of a most interesting "speed-effect," accompanied by a permanent structural change after stressing at high speeds, has been found in direct reversed-stress fatigue tests on 70:30 brass. This material exhibited a marked yield point when statically loaded at about 10,800 lbs./in.^{2}, and yielding at this stress was also noted to occur under slow cycles of reversed stress.

In these conditions, specimens that had been stressed above the yield point could be distinguished by X-ray examination as possessing a structure broken up into widely oriented crystallites. When tested in a high frequency fatigue-testing machine at 2,200 cycles/min., however, it was found that a stress as great as 20,000 lbs./in.^{2} could be applied without producing any marked elongation or causing any dispersal of the structure into crystallites.

Moreover, after this high-frequency stressing, the original yield point was permanently raised and the material would withstand a static load of over 22,500 lbs./in.^{2} without showing signs of yielding. It is suggested that the change in properties is brought about by the storage of an appreciable amount of internal strain. In evidence, it is shown that the high-frequency stressing brings about a measurable volume expansion.

JCC (3b)

Testing and Control 4

METHODS, EQUIPMENT

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings, Surface Measurements. Metallographic Structure and Constitution.

Spot Test for Chromium Plate

"NOTES ON THE SPOT TEST FOR THICKNESS OF CHROMIUM COATINGS." W. BLUM & W. A. OLSON (Nat'l. Bur. Standards) *Proc. Am. Electroplaters' Soc.*, June 1940, Preprint, 3 pp. Discussion.

The spot test for the thickness of chromium coatings consists in placing a drop of concentrated hydrochloric acid on the chromium and noting the interval of time from the beginning to the cessation of gas evolution.

The discrepancies observed in the use of this test are due partly to the high temperature coefficient of the rate of solution of chromium and the large effect of the concentration of the acid, which is more critical than was formerly realized. Chromium dissolves at a maximum rate in an acid of specific gravity of 1.15-1.16.

The recommended procedure specifies an acid having a specific gravity of 1.180 ± 0.002 at 60°/60° F. (11.5 $N \pm 0.2 N$), which dissolves chromium at about 60% of the maximum rate. The time required to dissolve 0.00001 in. of chromium varies from 13.5 sec. at 18° C. (64° F.) to 7.5 sec. at 30° C. (86° F.) The reproducibility of measurements made by a single observer are about 10%, but the results of different observers may vary as much as 20%. AB (4)

New Method for Determining Hydrogen in Steel

"ESTIMATION OF HYDROGEN IN STEEL." W. C. NEWELL. *Iron & Steel*, Vol. 13, No. 9, May 1940, pp. 321-323. Description of apparatus and operation.

A diagram and complete details of a simple apparatus developed at Brown-Firth research laboratories in England for the accurate estimation of hydrogen in metals are included with a discussion of its performance. Instead of the cumbersome and costly vacuum fusion method, this technique employs only vacuum heating to temperatures near 600° C.

In this thermal range, except in some isolated steels, hydrogen is evolved completely from a cylinder ½-in. in diam. and ½-in. long in 1 hr. Heating is done by means of an ordinary resistance furnace and temperatures are measured by a thermocouple. The method satisfactorily checks results on identical samples run by the vacuum fusion method. A clever system of mercury lift and magnetic rams allows several samples to be run in succession without disturbing the vacuum.

Curves are included showing the hydrogen content *vs.* time at several different temperatures. At any temperature above 500° C. the maximum amount of hydrogen is evolved in less than 1 hr. For more stubborn steels in which lattice variations or structural differences set up resistance to hydrogen diffusion, this time can be extended. A temperature of 400° C. appears to be too low for practical purposes as diffusion is too slow. Above 700° C. small amounts of carbon monoxide and nitrogen are evolved, so the practice is standardized at 600° C. for 1 hr. After applying this technique to some samples they were run in the vacuum fusion apparatus, but gave no further hydrogen pickup—attesting to the suitability of the method.

The apparatus not only can be applied to a practical estimation of the deleterious effects of hydrogen, but possesses the necessary accuracy for fundamental studies of gas-metal equilibria and the solution and diffusion of hydrogen in alloys. HFT (4)

Fatigue Testing of Welds

"Welds and the Testing of Their Endurance." John H. Hruska (Electro-Motive Corp.) *Iron Age*, Vol. 145, May 16, 1940, pp. 33-37. Descriptive.

The test method described is claimed to be superior to previously used fatigue tests of welds. Uniform testing and duplicable interpolation is possible. Specimens may be removed from test plates or finished assembly provided they are larger than 3½ x 2¼ in. At times fatigue strength should be checked in both the longitudinal and the transverse directions.

A special profile cutter made from high grade high-speed steel may be used. The test specimens were finished on a surface grinder to a thickness of 0.100 in. ± 0.0005 in. Edges were touched up by hand polishing. The specimen was inserted in the vise of a Krouse constant deflection type repeated-bending machine, and subjected to cycles of completely reversed stress. The other end of the specimen is clamped into the loading bearing, which is activated by the bar of the variable throw crank. The throw may be set at any deflection of the cantilever beam. The testing machine, which operated at 1750 reversals/min., required a ⅓-h.p. motor. A counted located at the rear recorded in 1,000 r.p.m.

When fracture of the specimen occurs, the rotary motion of the eccentric virtually caused the connecting rod to hit the stop to the right of the eccentric, automatically turning off the switch to the motor. If the welds are to be tested under corrosive conditions, the vise may be replaced by a U-shaped adaptor, and the entire end immersed in the desired solution.

Determination of the bending stresses is based on obtaining load deflection characteristics for representative samples from each series of the tested welds. A simple apparatus used by the author consisted of an exact copy of the vise of the testing machine, with the cantilever end of the specimen equipped with an attachment similar to the loading bearing. [*In some laboratories a rig is used to calibrate the specimen as its own dynamometer while it is in place in the testing machine.*—H.F.M.]

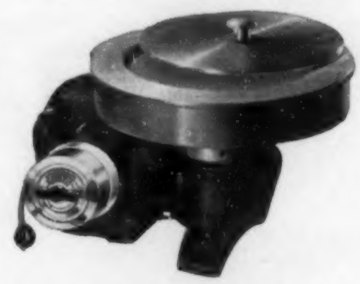
Point loading, duplicate measurements by dial indicators and means for checking stresses caused by applied load increments were provided. Deflection was selected to approach the setting for a given stress in the regular tester. Actual data for calculating were obtained by interpolation on a load-deflection curve. From the figures obtained, the static bending stresses may be computed by the usual flexure formula. [*Mr. Hruska states that tests of individual welded pieces under service conditions would be desirable but are not feasible. Tests of full size welded pieces and of large welded specimens are in progress in at least one laboratory in the United States and in several laboratories abroad. Mr. Hruska's specimens with ground-finish surfaces do not give information as to the irregular surface at a welded joint. They are, however, valuable as giving data as to the fatigue strength of the metal in weld, in base metal, and in junction metal.*—H.F.M.] VSP (4)

Tests for Heat-Brittleness

Testing Steels for Embrittlement at Elevated Temperatures ("Prufung von Stählen auf Versprödung bei höheren Temperaturen") E. Siebel & K. Wellinger. *Archiv Eisenhüttenw.*, Vol. 13, Mar. 1940, pp. 387-396. Original research.

Heating at elevated temperatures has an embrittling effect on chromium-nickel-molybdenum steels such as are used for staybolts. The susceptibility to such embrittlement may be detected by notched-bar impact tests after heating to about 950° F. under a tensile load. As a result of this treatment, the grain boundaries are more sharply brought out after etching.

In a chromium-nickel-molybdenum steel containing 0.12% C, 0.73 Cr, 1.61 Ni and 0.79 Mo, the most pronounced embrittlement took place upon loading and heating to 875° F. By loading cylindrical notched specimens at 950° F. to fracture, the susceptibility of steels toward a brittle type of fracture could be determined in a short time. Such tests may be useful in determining whether steels might be expected to give a non-ductile type of fracture after prolonged service at elevated temperatures. [*See also the digest "Irons and Steels at High Temperatures" on page 344 of this issue.*] SE (4)



books

Metal Physics

Crystal Chemistry and Physics of Metallic Materials. Introduction for Engineers (Kristallchemie und Kristallphysik metallischer Werkstoffe. Eine Einführung für Ingenieure). *By Franz Halla. Published by J. A. Barth, Leipzig, 1939. Paper, 6¼x9¼ in., 308 pages. Price 27 RM.*

The subtitle states that this is "an introduction for the engineer." Perhaps the future metallurgical engineer will grasp and utilize the high-brow matter included, but it's strong meat for the average present-day metallurgical engineer, since it deals, not with engineering properties, but with the laws of physics that underlie the behavior of metals. Many of these "laws" are so vaguely understood, and so difficult to prove or disprove experimentally, that they are hard to grasp, still harder to apply. Most of the topics represent a crude groping after some plausible theory, whose outlines are still too vague to allow its being pictured in understandable fashion to those who have not already put much time upon thinking these matters over.

This is no criticism of the book, it merely means that one needs a point of view and a background approaching those of Professors Mathewson and Mehl before the book conveys much to the reader. When the topics begin to approach the stage where the reader is hopeful that engineering data will be presented as showing the utility of the theory, the author turns to another topic, so the net result is a pretty high-brow volume.

Lattice structure, stereographic projections, coordination numbers, quantum mechanics in relation to the metallic state, single crystals, mosaic structure, kinetic theories of diffusion, lattice deformation, rolling texture, pole figures, recrystallization, thermodynamics, anisotropy, ferromagnetism, etc., are topics dealt with in the first half of the book. In the latter half, multicomponent systems, solid solutions, the iron-carbon diagram, superstructures, intermetallic phases, reactions in solid phases, reaction velocity, precipitation, etc., approach the more familiar physical metallurgy more closely.

The material is hard to read at best, doubly so in German. The presentation appears as simple as the nature of the material will allow, and is doubtless as accurate as the state of knowledge will permit. Many sections are quite brief and leave the impression that more should be said to clear up the topic. In these cases there probably isn't much more that can be said.

For its type, the book seems very good. However, the metallurgical engineer who picks it up with the expectation of immediately grasping all the thoughts of the theoretical physicist upon metals will find that the miracle of making these theories easily intelligible to him has not been performed.—H. W. Gillett.

Metallurgy

An Outline of Metallurgical Practice—Second Edition. *By Carle R. Hayward. Published by D. Van Nostrand Co., New York, 1940. Cloth, 6½ x 9 in., 690 pages. Price $7.50.*

The first edition was published in July, 1929, since which time new metallurgical processes have been developed and older ones improved. This has happened despite the fact that less money has been available for research and development, due to the depression, says the author. As stated in the preface to the first edition, this volume is not intended to replace any work which has yet appeared, but is designed to occupy a new field for satisfying two demands—first, to meet the desire of many engineers for a quick reference book that will give modern practice in extracting and refining most of the metals as well as information regarding the sources, uses and important alloys of the metals; second, to assist students starting metallurgical studies with no practical experience and little knowledge of the subject.

The new edition has chapters on the following metals: Cu, Pb, Zn, Al, Ni, Sn, Hg, Sb, As, Bi, Cd, Co, Mg, Be, Au, Ag, Pt, Cr, W, Mn, V, Mo and Zr, with two on Iron and Steel and Non-Ferrous Metals. Discussions of beryllium and zirconium are added to this edition, and rightly so. The chapter on non-ferrous alloys has been slightly enlarged and equilibrium diagrams brought up to date. Changes in the text and in the illustrations have been made wherever considered necessary, so as to represent modern practice. Modern developments which could aptly have been briefly included are: Powder metallurgy and metal hydrides.

On the whole the author has done a good job and fulfilled the purpose of providing a quick reference book for the student in his early years.—E. F. Cone.

German Copper Alloy Handbook

Handbook of Non-Ferrous Metals: Copper and its Alloys (Werkstoff-handbuch Nichteisenmetalle: Abschnitte D-F, Kupfer, Messing und Sonder-Messing, Bronze und Rotguss) *Edited by G. Masing, W. Wunder & H. Groeck. Published by VDI Verlag, Berlin, 1940. Paper, 6½ x 8½ in., 160 pages. Price 12 RM.*

The German analog of the A.S.M. "Metals Handbook" is under revision, the revised parts being supplied from time to time in loose leaf form. This section deals with copper and copper-base alloys.

Although nearly every part has been completely rewritten, comparison with the 1927 edition shows relatively few changes. Small amounts of additional information are given throughout. Much fuller as well as more up to date treatment is given to condenser tubing, rolled bronze, soldering and welding, effect of temperature on properties and in the equilibrium diagrams for copper-zinc and copper-tin alloys. A few new references are given, but the documentation is sparse.

One is justified in concluding that metallurgical engineers knew pretty nearly as much about copper and its alloys a dozen years ago as they do now.—H. W. Gillett.

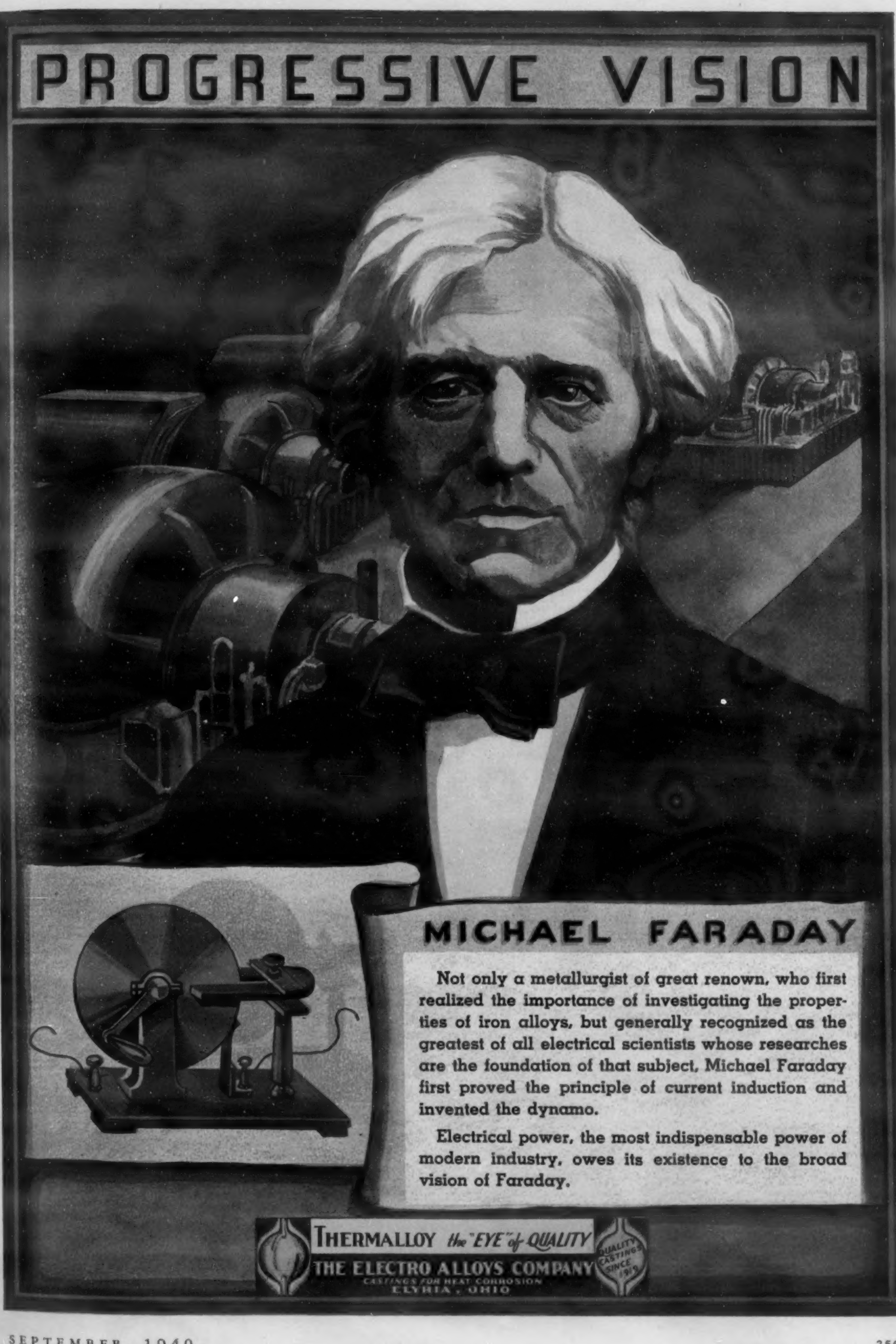
Other New Books

Alloy Iron and Steels—Patent Collection (Eisen- und Stahllegierungen Patentsammlung) 1st Part of Second Supplementary Volume of Gmelins Handbuch der anorganischen Chemie, 8th Edition. *By B. Habbel & A. Grützner. Published by Verlag Chemie, Berlin, 1940, Paper, 7 x 10¼ in., 623 pages. Price 47.25 RM.* This section covers patents issued in Australia, Belgium, Canada, Czechoslovakia, Holland, Italy, Poland and Russia and embraces silver-to-uranium alloys, with vanadium-to-zirconium to come later.

National Physical Laboratory Report for the Year 1939. *Published by H. M. Stationery Office, London, 1940. Paper, 6 x 9½ in., 100 pages. Price 75c.* Briefly describes topics under study in all branches of the N.P.L. including metallurgical projects in the engineering, metallurgy and physics divisions.

Plastics in Engineering. *By J. Delmonte. Published by Penton Publishing Co., Cleveland, 1940. Cloth, 6 x 9¼ in., 465 pages. Price $7.50.* Design and manufacturing problems in the use of plastics are featured.

Simple Methods of Analyzing Plating Solutions. Fifth Edition. *Published by Hanson-Van Winkle-Munning Co., Matawan, N. J., 1940. Paper, 5 x 7¼ in., 40 pages.* Free on request of publisher.


PROGRESSIVE VISION
MICHAEL FARADAY
Not only a metallurgist of great renown, who first realized the importance of investigating the properties of iron alloys, but generally recognized as the greatest of all electrical scientists whose researches are the foundation of that subject, Michael Faraday first proved the principle of current induction and invented the dynamo.
Electrical power, the most indispensable power of modern industry, owes its existence to the broad vision of Faraday.
THERMALLOY the "EYE" of QUALITY
THE ELECTRO ALLOYS COMPANY
CASTINGS FOR HEAT CORROSION
ELYRIA, OHIO

METALLURGICAL ENGINEERING

shop notes

"Cold Shot" on Die Castings

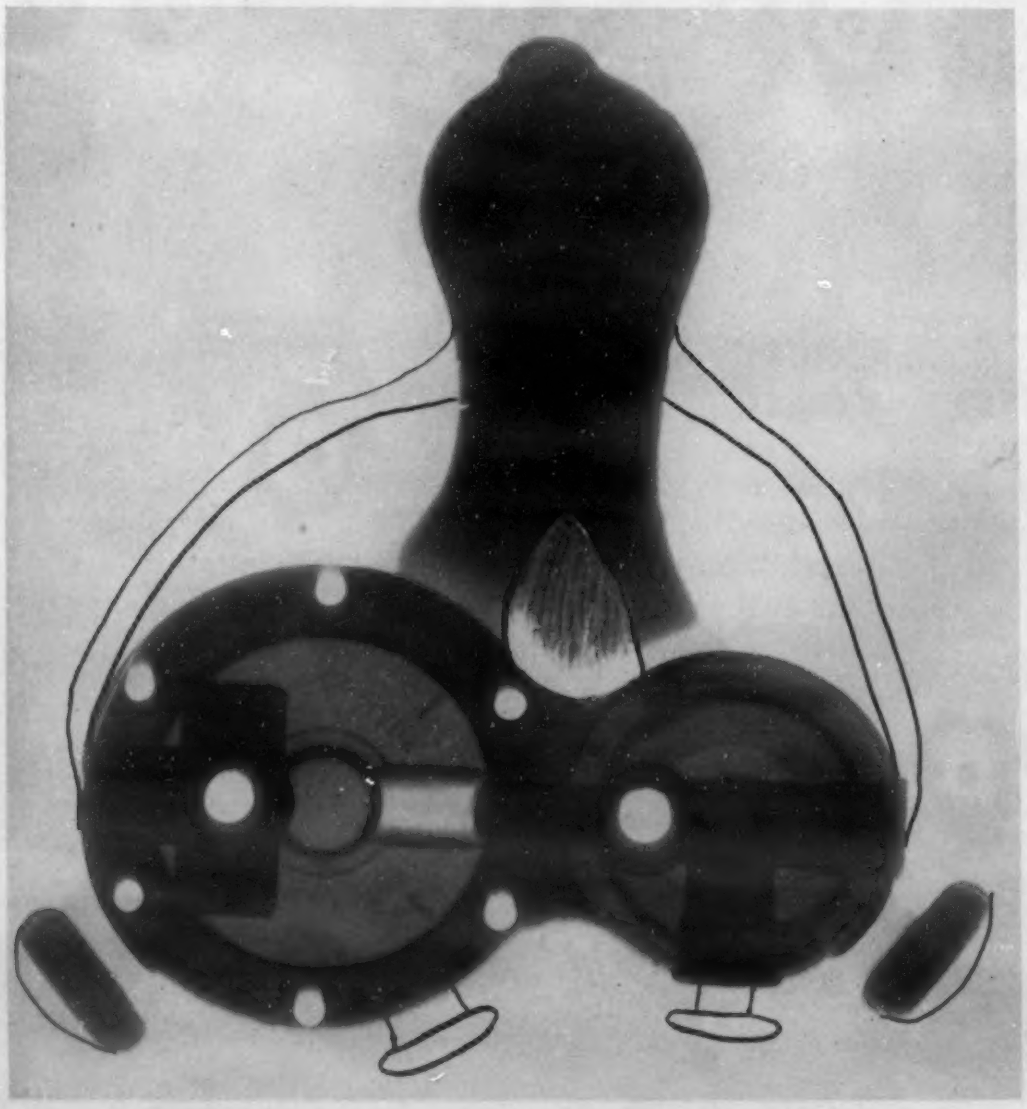
by H. R. Isenburger
St. John X-Ray Service, Inc.

A manufacturer of die castings recently reported considerable trouble with so-called "cold shot" on the surface of his castings.

The die castings involved were two small automotive equipment housings made in one die. The metal was a zinc alloy, and the cross-sections of the castings varied from very thin to comparatively heavy. The two die castings, complete with gate and overflows, were subjected to X-ray inspection.

The exograph, reproduced herewith, indicates that the flow of metal is uneven, with the metal cooling too fast in certain parts of the die. This condition is very often the cause of "cold shot" surfaces, and can usually be overcome by appropriate modification in gate and overflow design. The changes recommended for the die casting under discussion are indicated by the drawn-in lines on the illustration.

Thus, part of the gate should be eliminated where it feeds into the die castings. Two additional runners from the gate should feed the castings on each side. The overflows could be somewhat larger, and two additional small ones could be added, although the last may not be absolutely necessary.



Copper Plating and Tinning of Bearing Shells for Babbitting

by W. H. Tait
International Tin Research and Development Council

Bearing shells should be tinned before babbitting, and with shells of cast iron or alloy steel the best results are obtained by depositing a thin adherent coating of copper before tinning. In order to obtain good adhesion of the intermediate layer of copper, it is essential to etch the shells anodically before plating them.

Use of the method described below has resulted in specimens that under tensile test actually broke in the cast iron while the bond between the white metal and the cast iron remained sound.

The shells should be degreased by heating in a low-temperature oven if the cutting oil used is volatile. Trichlorethylene vapor degreasing is suitable for shells on which mineral-oil lubricants were used. Best practice is to use a soluble cutting oil and degrease in a boiling caustic solution such as the following:

Washing soda (sodium carbonate)	6 oz./gal.
Caustic soda (sodium hydroxide)	2 " "
Trisodium phosphate	2 " "
Sodium metasilicate	2 " "

A few minutes in this bath will remove soluble oils, but an hour or two may be necessary for mineral oils although some proprietary detergents are able to remove the latter in 5 or 10 min. Cathodic degreasing in a boiling alkaline bath is also very effective; the bath is contained in an iron pot connected to the positive poles of a 12-volt battery, with the negative pole connected to the bearing shell.

For anodic etching, the degreased shell is attached to the positive pole of a 12-volt battery, the other pole of which is connected to a lead-lined tank containing 50 per cent cold sulphuric acid (Sp. G. 1.40). The shell is lowered into the acid, and at first the surface of the shell blackens, but after 15 sec. it clears to a silvery gray and begins to evolve oxygen freely—an indication that the etch is adequate.

The shell is removed from the etching bath, rinsed and transferred to a standard cyanide copper plating bath. A layer of copper 0.002-0.003 in. thick should be deposited; this will require from 1 to 2 hrs.

The copper-plated shell is now ready to be brushed with flux and immersed in the tinning bath. Copper tins very readily at 465 to 485 deg. F.; if higher temperatures are used, the copper coating may be removed and the non-tinnable cast iron or steel exposed.

Heat treaters are always looking for simple methods of keeping work off the hearth in box type hardening furnaces. A cast alloy grid having 6 small legs has been found very suitable for this purpose. By loading heavier work on this grid rather than directly on the hearth, heating time is speeded up considerably and temperature uniformity is improved. The legs can be rounded to avoid digging into the hearth as the grid is pushed in and out.

—Heat Treating Hints, Lindberg Engineering Co.

Salt Baths for Nickel

by W. A. Mudge
The International Nickel Co., Inc.

The use of molten salt baths for annealing small wrought parts of Monel and nickel is often advantageous.

A mixture of 56 per cent sodium carbonate and 44 per cent sodium chloride (by weight), which melts at about 1180 deg. F., is highly satisfactory up to 1500 deg. F. Because of the intimate contact between the parts to be annealed and the molten salts, the former quickly reach the bath temperature, and after 20 to 60 min. the parts may be withdrawn, quenched in water and flash-pickled to remove oxidation and traces of adhering salts.

This final pickle is necessary if a bright-surfaced article is required, since salt annealing of these metals is not *bright* annealing. For flash pickling, the following solution, used at 70 to 100 deg. F. in earthenware, glass or ceramic containers, is satisfactory:

Water .... 1 gal.
Sulphuric Acid (60° Be)... 1½ gal.
Nitric Acid (38° Be)........ 2¼ gal.
Allow to cool and add ¼ lb. of common salt.

The operator should always be certain that the salt bath is sulphur free. This can be done by exposing thin strips of Monel or nickel in the molten salt for 4 to 6 hrs., then removing, quenching and finally bending to determine the presence or absence of intergranular attack.

Salt baths containing harmful sulphur may be made innocuous by treatment with a 25 per cent finely-ground charcoal and 75 per cent borax mixture (by volume). This should be added to the molten salts and stirred intermittently for about 4 hrs. The effectiveness of the addition may be determined by the exposure test just described.

The presence of the small amount of borax in the bath will also assist in the removal of small particles of adhering salt on quenching and flash pickling.

In cutting steels with carbide tools, tool life is markedly increased by the use of coolants, particularly soluble oil. The coolant pump, tank and pipe should be of large capacity to assure ample volume of coolant. The latter should leave the nozzle under sufficient pressure to force it against the tool and the work, and should be so directed that the obstruction caused by the rapidly-forming chip does not interfere with the flow. This can be accomplished by piping the coolant from beneath the tool or from each side thereof.—"Recommendations for Machining Steel," Carboloy Co., Inc.

Iron Fireman stoker transmissions embody forged gears, according to the manufacturer, because the forgings are of uniform density and free from blowholes, because grain structure can be controlled to provide maximum strength at a given point, and because the smooth, clean-surfaced gears lend themselves to fitting into jig fixtures more easily.— *Drop Forging Topics,* Drop Forging Assoc.

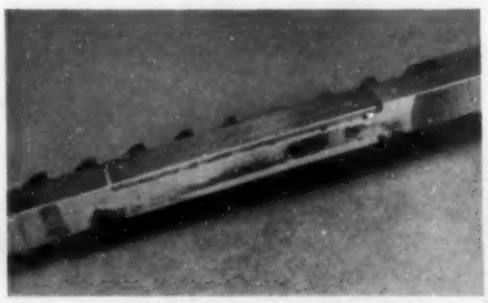
Send in your "shop notes." The editors will pay for all original material accepted.

Torch Brazing a Broken Tool

by R. N. Chapin
Air Reduction Sales Co.

Sometimes a shop is faced with a real problem when an expensive cutting tool breaks and the expected delay in replacing it threatens to disrupt production schedules. If the break is clean, it can often be repaired, but the joint must usually be made by some method that does not affect the hardness of the cutting edge. Under such circumstances, a satisfactory and highly economical job can often be done by silver-alloy brazing as the following case history indicates.

At the plant of the S. & S. Corrugated Paper Machinery Co., Inc., Brooklyn, N. Y., a high speed steel broach used in cutting ⅜-in. keyways broke in service. The tool is used constantly on a variety of work and delay in replacing it would be as serious a matter as the cost of a new tool ($72.75). It was therefore decided to braze the break with a silver alloy (Easy-Flo, manufactured by Handy & Harman, New York) that runs freely at a low temperature, 1175 deg. F., and to join 2 reinforcing strips of high speed steel to the sides, as shown in the illustration.



The sides of the broach were undercut ⅛ in. for a distance of 1¾ in. on both sides of the break on a surface grinder. These surfaces were then cleaned thoroughly and covered with a suitable flux (Handy Flux, also made by Handy & Harman, was used) which is completely liquid at 1100 deg. F. The two high speed steel reinforcing strips were formed to fit the recesses cut in the sides of the broach and were also fluxed. Then the joint was assembled with inserts of the brazing alloy in the form of 0.005 in. sheet between the reinforcing strips and the body of the broach, and the whole clamped together.

Heat was applied to the side opposite the cutting teeth, using an oxyacetylene torch with a No. 5 Airco tip regulated to a soft (reducing) flame. At a faint-red, even heat the brazing alloy insert melted and penetrated the fracture, joining the carefully butted broken parts. Air cooling followed, because of the type of steel involved.

The joint was sound, the cutting edge hardness had not been affected, and the broach did not warm to a harmful degree. The repaired broach has been in regular service for over 3 months and is doing its job as well as a new tool. The total materials and labor cost was only $6.60 (of which only $0.60 was gases, brazing alloy and flux)—a considerable saving over the $72.75 new-tool cost.

In splicing the ends of aluminum cable, steel-reinforced, the aluminum outer stranding must be cut back, but the center steel reinforcing must not be even nicked. Better for this job than bolt cutters (which ultimately sever the cable completely) or hack saws (which are tedious) are ordinary cow dehorners, which do a perfect trimming job in a jiffy. Stops on the dehorner allow the aluminum strands to be trimmed back without nicking the steel core.
—*Aluminum News Letter,* Aluminum Co. of America.

Straightening Bent Shafts

by A. B. Gordon
Linde Air Products Co.

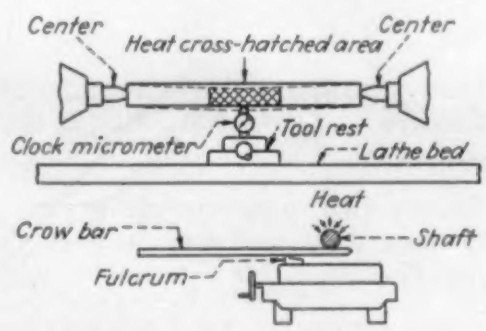
Shafts are often bent through mechanical or thermal damage in service, or warped in treatment, fabrication or service. For straightening such shafts, the oxyacetylene blowpipe can be most conveniently and economically used.

A common procedure is, first, to set up the shaft in a lathe and rotate it in order to find the bent section, using a clock micrometer as illustrated in the sketch. The shaft is rotated 360° to measure the difference between the maximum and minimum throw of the bent section. The outside of the bend is next positioned at the bottom and the bent area heated to a visible red with the blowpipe, as shown.

Pressure is then applied to the heated area with a crowbar blocked up on the lathe bed to force the warped section back into line. The shaft is pried upward one-half the amount of throw and then is checked again for trueness; the entire procedure should be repeated, if necessary, until the shaft is absolutely true.

In an alternative method, wedges of the correct size are driven between the outside of the bend and the lathe bed, and the shaft is heated at the inside of the bend so that the stress set up by the driven wedge will force the shaft back in line.

If the bent shaft is too long to be set up in a lathe, it may be left in its hangers.



After checking the hanger bearings for firmness, a measuring fixture comprising a clock micrometer blocked against the ceiling may be employed as above to determine the point and amount of bend. The outside of the bend is then positioned at the top and the high spot is heated with the blowpipe and forced back into line by means of a jack with its base blocked against the ceiling. The shaft is jacked downward a little more than half the amount of throw measured by the clock micrometer, then heated, remeasured, and reheated and straightened again, if necessary.